PROCEEDINGS

OF THE

TWENTIETH ANNUAL CONVENTION

OF THE

American Railway Engineering Association

HELD AT THE

CONGRESS HOTEL, CHICAGO, ILLINOIS

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CONSTITUTION

CONSTITUTION.

REVISED AT THE FIFTH, EIGHTH AND TWELFTH ANNUAL CONVENTIONS.

ARTICLE I.

NAME, OBJECT AND LOCATION.

Name.

1. The name of this Association is the AMERICAN RAILWAY ENGINEERING ASSOCIATION.

Object.

2. Its object is the advancement of knowledge pertaining to the scientific and economic location, construction, operation and maintenance of railways.

Means to Be Used.

3. The means to be used for this purpose shall be as follows:

(a) Meetings for the reading and discussion of reports and papers and for social intercourse.

(b) Investigation of matters pertaining to the objects of the Association through Standing and Special Committees.

(c) The publication of papers, reports and discussions.

(d) The maintenance of a library.

Responsibility.

4. Its action shall be recommendatory, and not binding upon its members.

Location of Office.

5. Its permanent office shall be located in Chicago, Ill., and the annual convention shall be held in that city.

ARTICLE II.

MEMBERSHIP.

Membership Classes.

1. The membership of this Association shall be divided into three classes, viz.: Members, Honorary Members and Associates.

Membership Qualifications.

(2) A Member shall be:

(a) Either a Civil Engineer, a Mechanical Engineer, an Electrical Engineer, or an official of a railway corporation, who has had not less

than five (5) years' experience in the location, construction, maintenance or operation of railways, and who, at the time of application for membership, is engaged in railway service in a responsible position in charge of work connected with the Location, Construction, Operation or Maintenance of a Railway; provided, that all persons who were Active Members prior to March 20, 1907, shall remain Members except as modified by Article II, Clause 9.

(b) A Professor of Engineering in a college of recognized standing.

Honorary Membership Qualifications.

3. An Honorary Member shall be a person of acknowledged eminence in railway engineering or management. The number of Honorary Members shall be limited to ten.

Associate Membership Qualifications.

4. An Associate shall be a person not eligible as a Member, but whose pursuits, scientific acquirements or practical experience qualify him to co-operate with Members in the advancement of professional knowledge, such as Consulting, Inspecting, Contracting, Government or other Engineers, Instructors of Engineering in Colleges of recognized standing, and Engineers of Industrial Corporations when their duties are purely technical.

Membership Rights.

5. (a) Members shall have all the rights and privileges of the Association.

(b) Honorary Members shall have all the rights of Members, except that of holding office, and shall be exempt from the payment of dues.

(c) Associates shall have all the rights of Members, except those of voting and holding office.

Age Requirement.

6. An applicant to be eligible for membership in any class shall not be less than twenty-five (25) years of age.

"Railway" Defined.

7. The word "railway" in this Constitution means one operated by steam or electricity as a common carrier, dependent upon transportation for its revenue. Engineers of street railway systems and of railways which are used primarily to transport the material or product of an industry or industries to and from a point on a railway which is a common carrier, or those which are merely adjuncts to such industries, are eligible only as Associates.

Changes in Classes.

8. A Member, elected after March 20, 1907, who shall leave the railway service, shall cease to be a Member, but may retain membership in the Association as an Associate, subject to the provisions of Article II, Clause 9; provided, however, if he re-enters the railway service, he shall be restored to the class of Members.

Supply Men.

9. Persons whose principal duties require them to be engaged in the sale or promotion of railway patents, appliances or supplies, shall not be eligible for, nor retain membership in any class in this Association, except that those who were Active Members prior to March 20, 1907, may retain membership as Associates; provided, however, that anyone having held membership in the Association and subsequently having become subject to the operation of this clause, shall, if he again becomes eligible, be permitted to re-enter the Association, without the payment of a second entrance fee.

Transfers.

10. The Board of Direction shall transfer members from one class to another, or remove a member from the membership list, under the provisions of this Article.

ARTICLE III.

ADMISSIONS AND EXPULSIONS.

Charter Membership.

1. The Charter Membership consists of all persons who were elected before March 15, 1900.

Application for Membership.

2. The Charter Membership having been completed, any person desirous of becoming a member shall make application upon the form prescribed by the Board of Direction, setting forth in a concise statement his name, age, residence, technical education and practical experience. He shall refer to at least three members to whom he is personally known, each of whom shall be requested by the Secretary to certify to a personal knowledge of the candidate and his fitness for membership.

Election to Membership.

3. Upon receipt of an application properly endorsed, the Board of Direction, through its Secretary, or a Membership Committee selected from its own members, shall make such investigation of the candidate's

fitness as may be deemed necessary. The Secretary will furnish copies of the information obtained and of the application to each member of the Board of Direction. At any time, not less than thirty days after the filing of the application, the admission of the applicants shall be canvassed by letter-ballot among the members of the Board, and affirmative votes by two-thirds of its members shall elect the candidate; provided, however, that should an applicant for membership be personally unknown to three members of the Association, due to residence in a foreign country, or in such a portion of the United States as precludes him from a sufficient acquaintance with its members, he may refer to well-known men engaged in railway or allied professional work, upon the form above described, and such application shall be considered by the Board of Direction in the manner above set forth, and the applicant may be elected to membership by a unanimous vote of the Board.

Subscription to Constitution.

4. All persons, after due notice from the Secretary of their election, shall subscribe to the Constitution on the form prescribed by the Board of Direction. If this provision be not complied with within six months of said notice, the election shall be considered null and void.

Reinstatement.

5. Any person having been a member of this Association, and having, while in good standing, resigned such membership, may be reinstated without the payment of a second entrance fee; provided his application for reinstatement is signed by five members certifying to his fitness for same, and such application is passed by a two-thirds majority of the Board of Direction.

Honorary Membership.

6. Proposals for Honorary Membership shall be submitted by ten or more Members. Each member of the Board of Direction shall be furnished with a copy of the proposal, and if, after thirty days, the nominee shall receive the unanimous vote of said Board, he shall be declared an Honorary Member.

Expulsions.

7. When charges are preferred against a Member in writing by ten or more Members, the Member complained of shall be served with a copy of such charges, and he shall be called upon to show cause to the Board of Direction why he should not be expelled from the Association. Not less than thirty days thereafter a vote shall be taken on his expulsion, and he shall be expelled upon a two-thirds vote of the Board of Direction.

Resignations.

8. The Board of Direction shall accept the resignation, tendered in writing, of any Member whose dues are fully paid up.

ARTICLE IV.

DUES.

Entrance Fee.

1. An entrance fee of $10.00 shall be payable to the Association through its Secretary with each application for membership; and this sum shall be returned to the applicant if not elected.

Annual Dues.

2. *The annual dues are $10.00, payable during the first three months of the calendar year.

Arrears.

3. Any person whose dues are not paid before April 1st of the current year shall be notified of same by the Secretary. Should the dues not be paid prior to July 1st, the delinquent Member shall lose his right to vote. Should the dues remain unpaid October 1st, he shall be notified on the form prescribed by the Board of Direction, and he shall no longer receive the publications of the Association. If the dues are not paid by December 31st, he shall forfeit his membership without further action or notice, except as provided for in Clause 4 of this Article.

Remission of Dues.

4. The Board of Direction may extend the time of payment of dues, and may remit the dues of any Member who, from ill-health, advanced age or other good reasons, is unable to pay them.

ARTICLE V.

BOARD OF DIRECTION.

Officers.

1. The officers of the Association shall be Members and shall consist of:

A President,
A First Vice-President,
A Second Vice-President,
A Treasurer,
A Secretary,
Nine Directors,

*The annual payment of $10.00 made by each member is to be subdivided and credited on the books of the Association, as follows: To member's subscription to the Bulletin, $5.00; annual dues, $5.00.

who, together with the five latest living Past-Presidents who are Members, shall constitute the Board of Direction in which the government of the Association shall be vested, and who shall act as Trustees, and have the custody of all property belonging to the Association.

Vice-Presidents' Priority.

2. The offices of First and Second Vice-Presidents shall be determined by the priority of their respective dates of election.

Terms of Office.

3. The terms of office of the several officers shall be as follows:

President, one year.
Vice-Presidents, two years.
Treasurer, one year.
Secretary, one year.
Directors, three years.

Officers Elected Annually.

4. (a) There shall be elected at each Annual Convention:

A President,
One Vice-President,
A Treasurer,
A Secretary,
Three Directors.

(b) The candidates for President and for Vice-President shall be selected from the members of the Board of Direction.

Conditions of Re-election of Officers.

5. The office of President shall not be held twice by the same person. A person who shall have held the office of Vice-President or Director shall not be eligible for re-election to the same office until at least one full term shall have elapsed after the expiration of his previous term of office.

Term of Officers.

6. The term of each officer shall begin with his election and continue until his successor is elected.

Vacancies in Offices.

7. (a) A vacancy in the office of President shall be filled by the First Vice-President.

(b) A vacancy in the office of either of the Vice-Presidents shall be filled by the Board of Direction by election from the Directors. A Vice-Presidency shall not be considered vacant when one of the Vice-Presidents is filling a vacancy in the Presidency.

(c) Any other vacancies for the unexpired term in the membership of the Board of Direction shall be filled by the Board.

(d) An incumbent in any office for an unexpired term shall be eligible for re-election to the office he is holding; provided, however, that anyone appointed to fill a vacancy as Director within six months after the term commences shall be considered as coming within the provision of Article V, Clause 5.

Vacation of Office.

8. When an officer ceases to be a Member of the Association, as provided in Article II, his office shall be vacated, and be filled as provided in Article V, Clause 7.

Disability or Neglect.

9. In case of the disability or neglect in the performance of his duty, of an officer, the Board of Direction, by a two-thirds majority vote of the entire Board, shall have power to declare the office vacant, and fill it as provided in Article V, Clause 7.

ARTICLE VI.

NOMINATION AND ELECTION OF OFFICERS.

Nominating Committee.

1. (a) There shall be a Nominating Committee composed of the five latest living Past-Presidents of the Association, who are Members, and five Members not officers.

(b) The five Members shall be elected annually when the officers of the Association are elected.

Number of Candidates.

2. It shall be the duty of this Committee to nominate candidates to fill the offices named in Article V, and vacancies in the Nominating Committee caused by expiration of term of service, for the ensuing year, as follows:

Office to be Filled.	Number of Candidates to be named by Nominating Committee.	Number of Candidates to be Elected At Annual Election of Officers.
President	1	1
Vice-President	1	1
Treasurer	1	1
Secretary	1	1
Directors	9	3
Nominating Committee	10	5

Chairman.

3. The Senior Past-President shall act as permanent chairman of the Committee, and will issue the call for meetings. In his absence from meetings, the Past-President next in age of service shall act as Chairman pro tem. at the meeting.

Meeting of Committee.

4. Prior to December 1st each year, the Chairman shall call a meeting of the Committee at a convenient place and, at this meeting, nominees for office shall be agreed upon.

Announcement of Names of Nominees.

5. The names of the nominees shall be announced by the permanent Chairman to the President and Secretary not later than December 15th of the same year, and the Secretary shall report them to the members of the Association on a printed slip not later than January 1st following.

Additional Nominations by Members.

6. At any time between January 1st and February 1st, any ten or more Members may send to the Secretary additional nominations for the ensuing year signed by such Members.

Vacancies in List of Nominees.

7. If any person so nominated shall be found by the Board of Direction to be ineligible for the office for which he is nominated, or should a nominee decline such nomination, his name shall be removed and the Board may substitute another one therefor; and may also fill any vacancies that may occur in this list of nominees up to the time the ballots are sent out.

Ballots Issued.

8. Not less than thirty days prior to each Annual Convention, the Secretary shall issue ballots to each voting member of record in good standing, with a list of the several candidates to be voted upon, with the names arranged in alphabetical order when there is more than one name for any office.

Substitution of Names.

9. Members may erase names from the printed ballot list and may substitute the name or names of any other person or persons eligible for any office, but the number of names voted for each office on the ballot must not exceed the number to be elected at that time to such office.

Ballots.

10. (a) Ballots shall be placed in an envelope, sealed and endorsed with the name of the voter, and mailed or deposited with the Secretary at any time previous to the closure of the polls.

(b) A voter may withdraw his ballot, and may substitute another, at any time before the polls close.

Invalid Ballots.

11. Ballots not endorsed or from persons not qualified to vote shall not be opened; and any others not complying with the above provisions shall not be counted.

Closure of Polls.

12. The polls shall be closed at twelve o'clock noon on the second day of the Annual Convention, and the ballots shall be counted by three tellers appointed by the Presiding Officer. The ballots and envelopes shall be preserved for not less than ten days after the vote is canvassed.

Requirements for Election.

13. The persons who shall receive the highest number of votes for the offices for which they are candidates shall be declared elected.

Tie Vote.

14. In case of a tie between two or more candidates for the same office, the members present at the Annual Convention shall elect the officer by ballot from the candidates so tied.

Announcement.

15. The Presiding Officer shall announce at the convention the names of the officers elected in accordance with this Article.

First Nominating Committee.

16. Except as to the Past-Presidents, the first Nominating Committee and the three additional Directors provided for shall be appointed by the Board of Direction, one of the Directors for one year, one for two years and one for three years.

ARTICLE VII.

MANAGEMENT.

Duties of President.

1. (a) The President shall have general supervision of the affairs of the Association, shall preside at meetings of the Association and of the Board of Direction, and shall be ex-officio member of all Committees, except the Nominating Committee.

(b) The Vice-Presidents, in order of seniority, shall preside at meetings in the absence of the President and discharge his duties in case of a vacancy in his office.

Duties of Treasurer.

2. The Treasurer shall receive all moneys and deposit same in the name of the Association, and shall receipt to the Secretary therefor. He shall invest all funds not needed for current disbursements as shall be ordered by the Board of Direction. He shall pay all bills, when properly certified and audited by the Finance Committee, and make such reports as may be called for by the Board of Direction.

Duties of Secretary.

3. The Secretary shall be, under the direction of the President and Board of Direction, the Executive Officer of the Association. He shall attend the meetings of the Association and of the Board of Direction, prepare the business therefor, and duly record the proceedings thereof. He shall see that the moneys due the Association are collected and without loss transferred to the custody of the Treasurer. He shall personally certify to the accuracy of all bills or vouchers on which money is to be paid. He is to conduct the correspondence of the Association and keep proper record thereof, and perform such other duties as the Board of Direction may prescribe.

Auditing of Accounts.

4. The accounts of the Treasurer and Secretary shall be audited annually by a public accountant, under the direction of the Finance Committee of the Board.

Duties of Board.

5. The Board of Direction shall manage the affairs of the Association, and shall have full power to control and regulate all matters not otherwise provided in the Constitution.

Board Meetings.

6. The Board of Direction shall meet within thirty days after each Annual Convention, and at such other times as the President may direct. Special meetings shall be called on request, in writing, of five members of the Board.

Board Quorum.

7. Seven members of the Board shall constitute a quorum.

Board Committees.

8. At the first meeting of the Board after the Annual Convention, the following committees from its members shall be appointed by the

President, and shall report to and perform their duties under the supervision of the Board of Direction:

a. Finance Committee of three members.

b. Publication Committee of three members.

c. Library Committee of three members.

d. Outline of Work of Standing Committees of five members.

Duties of Finance Committee.

9. The Finance Committee shall have immediate supervision of the accounts and financial affairs of the Association; shall approve all bills before payment, and shall make recommendations to the Board of Direction as to the investment of moneys and as to other financial matters. The Finance Committee shall not have the power to incur debts or other obligations binding the Association, nor authorize the payment of money other than the amounts necessary to meet ordinary current expenses of the Association, except by previous action and authority of the Board of Direction.

Duties of Publication Committee.

10. The Publication Committee shall have general supervision of the publications of the Association.

Duties of Library Committee.

11. The Library Committee shall have general supervision of the Library, the property therein, and the quarters occupied by the Secretary; shall make recommendations to the Board with reference thereto, and shall direct the expenditure for books and other articles of permanent value, from such sums as may be appropriated for these purposes.

Duties of Committee on Outline of Work of Standing Committees.

12. The Committee on Outline of Work of Standing Committees shall present a list of subjects for committee work during the ensuing year at the first meeting of the Board of Direction after the Annual Convention.

Standing Committees.

13. The Board of Direction may appoint such Standing Committees as it may deem best, to investigate, consider and report upon questions pertaining to railway location, construction or maintenance.

Special Committees.

14. Special Committees to examine into and report upon any subject connected with the objects of this Association may be appointed from time to time by the Board of Direction.

Discussion by Non-Members.

15. The Board of Direction may invite discussions of reports from persons not members of the Association.

Sanction of Acts of Board.

16. An act of the Board of Direction which shall have received the expressed or implied sanction of the membership at the next Annual Convention of the Association shall be deemed to be the act of the Association, and shall not afterwards be impeached by any Member.

ARTICLE VIII.

MEETINGS.

Annual Convention.

1. The Annual Convention shall begin upon the third Tuesday in March of each year, and shall be held at such place in the City of Chicago as the Board of Direction may select.

Special Meetings.

2. Special meetings of the Association may be called by the Board of Direction, and special meetings shall be so called by the Board upon request of thirty Members, which request shall state the purpose of such meeting. The call for such meeting shall be issued not less than ten days in advance, and shall state the purpose and place thereof, and no other business shall be taken up at such meeting.

Notification of Annual Convention.

3. The Secretary shall notify all members of the time and place of the Annual Convention of the Association at least thirty days in advance thereof.

Association Quorum.

4. Twenty-five Members shall constitute a quorum at all meetings of the Association.

Order of Business.

5. (a) The order of business at annual conventions of the Association shall be as follows:

Reading of minutes of last meeting.
Address of the President.
Reports of the Secretary and Treasurer.
Reports of Standing Committees.
Reports of Special Committees.
Unfinished business.

New business.
Election of officers.
Adjournment.

(b) This order of business, however, may be changed by a majority vote of members present.

Rules of Order.

6. The proceedings shall be governed by "Robert's Rules of Order," except as otherwise herein provided.

Discussion.

7. Discussion shall be limited to members and to those invited by the presiding officer to speak.

ARTICLE IX.

AMENDMENTS.

Amendments.

1. Proposed amendments to this Constitution shall be made in writing and signed by not less than ten Members, and shall be acted upon in the following manner:

The amendments shall be presented to the Secretary, who shall send a copy of same to each member of the Board of Direction as soon as received. If at the next meeting of the Board of Direction a majority of the entire Board are in favor of considering the proposed amendments, the matter shall then be submitted to the Association for letter-ballot, and the result announced by the Secretary at the next Annual Convention. In case two-thirds of the votes received are affirmative, the amendments shall be declared adopted and become immediately effective.

GENERAL INFORMATION.

(Subject to change from time to time by Board of Direction.)

GENERAL RULES FOR THE PREPARATION, PUBLICATION AND CONSIDERATION OF COMMITTEE REPORTS.

(A) APPOINTMENT OF COMMITTEES AND OUTLINE OF WORK.

Standing Committees.

1. The following are Standing Committees:

I. Roadway.
II. Ballast.
III. Ties.
IV. Rail.
V. Track.
VI. Buildings.
VII. Wooden Bridges and Trestles.
VIII. Masonry.
IX. Signs, Fences and Crossings.
X. Signals and Interlocking.
XI. Records and Accounts.
XII. Rules and Organization.
XIII. Water Service.
XIV. Yards and Terminals.
XV. Iron and Steel Structures.
XVI. Economics of Railway Location.
XVII. Wood Preservation.
XVIII. Electricity.
XIX. Conservation of Natural Resources.
XX. Uniform General Contract Forms.
XXI. Economics of Railway Operation.
XXII. Economics of Railway Labor.

Special Committees.

2. Special Committees will be appointed from time to time, as may be deemed expedient, in the manner prescribed by Article VII, Clause 14, of the Constitution.

The following are Special Committees:

Stresses in Railroad Track.
Standardization.

Personnel of Committees.

3. The personnel of all Committees will continue from year to year, except when changes are announced by the Board of Direction. Ten per cent. of the membership of each Committee shall be changed each year.

Members of committees who do not attend meetings of committees during the year or render service by correspondence will be relieved and the vacancies filled by the Board at the succeeding Annual Convention.

Outline of Work.

4. As soon as practicable after each Annual Convention the Board of Direction will assign to each Committee the important questions which, in its judgment, should preferably be considered during the current year. Committees are privileged to present the results of any special study or investigation they may be engaged upon or that may be considered of sufficient importance to warrant presentation.

(B) PREPARATION OF COMMITTEE REPORTS.

General.

5. The collection and compilation of data and subsequent analysis in the form of arguments and criticism is a necessary and valuable preliminary element of committee-work.

Collection of Data.

6. Committees are privileged to obtain data or information in any proper way. The Secretary will issue circulars of inquiry, which should be brief and concise. The questions asked should be specific and pertinent, and not of such general or involved character as to preclude the possibility of obtaining satisfactory and prompt responses. They should specify to whom answers are to be sent, and should be in such form that copies can be retained by persons replying either by typewriter or blueprint.

Plan of Reports.

7. Committee reports should be prepared as far as practicable to conform to the following general plan:

(a) It is extremely important that every Committee should examine its own subject-matter in the "Manual" prior to each Annual Convention, and revise and supplement it, if deemed desirable, giving the necessary notice of any recommended changes in accordance with Clause 6 (a) of the General Rules for the Publication of the "Manual." If no changes are recommended, statement should be made accordingly.

(b) When deemed necessary, the previous report should be reviewed.

(c) Subjects presented in previous reports on which no action was taken should be resubmitted, stating concisely the action desired. It may not be necessary to repeat the original text in the report, reference to former publication being sufficient, unless changes in the previously published version are extensive. Minor changes can be explained in the text of the report.

Definitions.

(d) Technical terms used in the report, the meaning of which is not clearly established, should be defined, but defined only from the standpoint of railway engineering.

History.

(e) If necessary, a brief history of the subject-matter under discussion, with an outline of its origin and development, should be given.

Analysis.

(f) An analysis of the most important elements of the subject-matter should be given.

Argument.

(g) The advantages and disadvantages of the present and recommended practices should be set forth.

Illustrations.

(h) Illustrations accompanying reports should be prepared so that they can be reproduced on one page. The use of folders should be avoided as much as possible, on account of the increased expense and inconvenience in referring to them. Plans showing current practice, or necessary for illustration, are admissible, but those showing proposed definite design or practice should be excluded. Recommendations should be confined to governing principles.

Illustrations should be made on tracing cloth with heavy black lines and figures, so as to stand a two-thirds reduction; for example: To come within a type page (4 inches by 7 inches), the illustration should be made three times the above size.

To insure uniformity, the one-stroke, inclined Gothic lettering is recommended.

Photographs should be clear and distinct silver prints.

Conclusions.

(i) The conclusions of the Committee which are recommended for publication in the Manual should be stated in concise language, logical

sequence, and grouped together, setting forth the principles, specifications, definitions, forms, tables and formulas included in the recommendation. Portions of the text of the report which are essential to a clear interpretation and understanding of the conclusions, should be included as an integral part thereof.

(c) PUBLICATION OF COMMITTEE REPORTS.

Reports Required.

8. (a) Reports will be required from each of the Standing and Special Committees each year.

(b) Although several subjects may be assigned to each Committee by the Board of Direction, a full report on only one subject is expected at each Annual Convention, but the preliminary work on some of the remaining subjects should be in progress, and, when deemed advisable, partial reports of progress should also be presented. This method allows time for their proper preparation and consideration.

Date of Filing Reports.

9. Committee reports to come before the succeeding convention for discussion should be filed with the Secretary not later than November 30th of each year.

10. Committees engaged upon subjects involving an extended investigation and study are privileged to present progress reports, giving a brief statement of the work accomplished, and, if deemed expedient, a forecast of the final report to be presented.

Publication of Reports.

11. Committee reports will be published in the Bulletin in such sequence as the Board of Direction may determine, for consideration at the succeeding convention. Reports will be published in the form presented by the respective Committees. Alterations ordered by the convention will be printed as an appendix to the report.

Written Discussions.

12. Committees should endeavor to secure written discussions of published reports. Written discussions will be transmitted to the respective Committees, and if deemed desirable by the Committee, the discussions will be published prior to the convention and be considered in connection with the report.

Verbal Discussions.

13. Each speaker's remarks will be submitted to him in writing before publication in the Proceedings, for the correction of diction and errors of reporting, but not for the elimination of remarks.

Sequence.

(D) CONSIDERATION OF COMMITTEE REPORTS.

14. The sequence in which Committee reports will be considered by the convention will be determined by the Board of Direction.

Method.

15. The method of consideration of Committee reports will be one of the following:

(a) Reading by title.

(b) Reading, discussing and acting upon each conclusion separately.

(c) By majority vote, discussion will be had on each item. Clauses not objected to when read will be considered as voted upon and adopted.

Final Action.

16. Action by the convention on Committee reports will be one of the following, after discussion is closed:

(a) Receiving as information.

(b) Receiving as a progress report.

(c) Adoption of a part complete in itself and referring remainder back to Committee.

(d) Adoption as a whole.

(e) Recommittal with or without instructions.

(f) Adoption as a whole.

(g) Recommendation to publish in the Manual.

NOTE.—An amendment which affects underlying principles, if adopted, shall of itself constitute a recommittal of such part of the report as the Committee considers affected.

The Chair will decline to entertain amendments which in his opinion lie entirely within the duties of the Editor.

(E) PUBLICATION BY TECHNICAL JOURNALS.

The following rules will govern the releasing of matter for publication in technical journals:

Committee reports, requiring action by the Association at the annual convention, will not be released until after presentation to the convention; special articles, contributed by members and others, on which no action by the Association is necessary, are to be released for publication by the technical journals after issuance in the Bulletin; provided, application therefor is made in writing and proper credit be given the Association, authors or Committees presenting such material.

GENERAL RULES FOR THE PUBLICATION OF THE "MANUAL."

Title.

1. The title of the volume will be "Manual of the American Railway Engineering Association."

2. The Board of Direction shall edit the Manual and shall have authority to withhold from publication any matter which it shall consider as not desirable to publish, or as not being in proper shape, or as not having received proper study and consideration.

Adoption of Reports Not Binding.

3. Matters adopted by the Association and subsequently published in the Manual shall be considered in the direction of good practice, but shall not be binding on the members.

Contents.

4. The Manual will only include conclusions relating to definitions, specifications and principles of practice as have been made the subject of a special study by a Standing or Special Committee and embodied in a Committee report, published not less than thirty days prior to the Annual Convention, and submitted by the Committee to the Annual Convention, and which, after due consideration and discussion, shall have been voted on and formally adopted by the Association. Subjects which, in the opinion of the Board of Direction, should be reviewed by the American Railroad Association, may be referred to that Association before being published in the Manual.

5. All conclusions included in the Manual must be in concise and proper shape for publication, as the Manual will consist only of a summary record of the definitions, specifications and principles of practice adopted by the Association, with a brief reference to the published Proceedings of the Association for the context of the Committee report and subsequent discussion and the final action of the Association.

Revision.

6. Any matter published in the Manual may be amended or withdrawn by vote at any subsequent Annual Convention, provided such changes are proposed in time for publication not less than thirty days prior to the Annual Convention, and in the following manner: (a) Upon recommendation of the Committee in charge of the subject; (b) upon recom-

mendation of the Board of Direction; (c) upon request of five members, made to the Board of Direction.

7. The Manual will be revised either by publishing a new edition or a supplemental pamphlet as promptly as possible after each Annual Convention.

BUSINESS SESSION

PROCEEDINGS

The object of this Association is the advancement of knowledge pertaining to the scientific and economic location, construction, operation and maintenance of railways. Its action is not binding upon its Members.

TUESDAY, MARCH 18, 1919

MORNING SESSION

The Twentieth Annual Convention of the American Railway Engineering Association was called to order by the President, Mr. C. A. Morse, Assistant Director of Operation, United States Railroad Administration, at 9:45 a. m.

The President:—The Twentieth Annual Convention of the American Railway Engineering Association will please come to order.

The first business in order is the reading of the Minutes of the last Annual Meeting. Inasmuch as these Minutes are quite voluminous and a copy has been furnished to each member, the Minutes will be considered approved unless there is objection. There being no objection, the Minutes stand approved as printed.

The privileges of the floor are extended to any railway officials present who are not members of the Association, and to professors of colleges and universities, and they are cordially invited to take part in the discussion.

We will extend that invitation still further and include manufacturers. We want anyone to get up who has anything to say on the subject.

The second order of business is the President's Address. Before starting that, I have an idea there are a lot of you would like to know what has become of the American Railway Engineering Association in connection with the negotiations which have been going on among the railroad associations, and in connection with a letter I sent out last Spring, and of which matter there has been a partial explanation sent out in one of the Bulletins. I want to say that the American Railway Engineering Association has retained its identity, but it has made a working arrangement with the newly-organized American Railroad Association by which the American Railway Engineering Association will do work in connection with construction and maintenance as part of the Engineering Section of that Association. In other words, instead of that Association organizing committees to do just what our committees are doing, it has been decided that after the committees of the American Railway Engineering Association have made their report at this Convention, these reports will be presented to the Fall Meeting of the American Railroad Association, with, if possible, the action of this convention on these committees' re-

ports, and it is felt that they will thereby be strengthened by the action of the American Railway Engineering Association Convention.

I would like to call attention to another point. In a letter that was sent out by the United States Railroad Administration to the Regional Directors, and through them to the Federal Managers, coming from the Director of Operation, he not only asked that the members of this Association and officials and employees of the railroads that were interested in maintenance, and could be spared from their other duties, be permitted to attend this Convention, but he added: "and take part in the discussions, and see the exhibit of railway appliances which is to be held." Therefore, you people have not only the duty of attending the sessions of the Convention, but you are expected to take part in the discussion, and you also are expected to attend the exhibit of the Railway Appliance Association, and make the boys feel good down there by looking over their exhibits.

PRESIDENT'S ADDRESS.

This is the Twentieth Annual Convention of this Association, and if we look back over the period covered by the life of the Association, and see the changes that have taken place in the physical character of the railroads of the country, we recognize that this covers a period of general reconstruction of our railroads, and of maintenance methods and requirements. This has been caused by the effort upon the part of the railroads to satisfy the demands of the public for better passenger service, more prompt freight service, better station facilities, and, coupled with this, greater safety to the traveling public and to employees.

Not only was the public making demands for better service and improved facilities, but about the same time there spread over the country a wave of anti-railroad legislation, and anti-railroad feeling, that resulted in the reduction of rates by legislative acts, or commission orders; a marked increase in railroad taxes, and a demand for all manner of expenditures by the railroads for the benefit of the public, such as elevation of tracks in cities, electrification of terminals, separation of grades, viaducts over railroad tracks in cities—all of which called for large expenditures with little or no earning power.

The result of all of this has been strenuous efforts on the part of the railroads to devise economies in methods of operation which would permit them to meet these conditions and continue to pay their fixed charges and dividends to their stockholders.

The prosperous condition of the country during this period with the resulting increase in business helped them to meet these conditions for a while, but in spite of increased business and increased operating efficiency, radical changes in equipment and roadway became necessary to keep down operating expenses.

First came the larger locomotives and cars, with increased axle loads, too heavy for the track and roadway provided up to that time. This

called for heavier rail and fastenings, more ties to the rail, and for ballast to support the track; this, in turn, called for wider embankments, wider cuts, better drainage, and stronger bridges. The object of the heavier locomotive being to haul more freight, which meant more cars; this called for the lengthening of passing tracks, and rebuilding of terminal yards to hold the longer trains. Increasing the size of the locomotive meant increasing length, which in turn called for longer turntables and transfer tables, larger engine houses and longer pits in locomotive repair shops.

The larger locomotive with its increased steaming capacity made it necessary to treat the natural water for boiler use, necessitating the rebuilding of water stations. Along with these changes came the need for improved coaling stations and cinder handling devices, and the enlarging and rebuilding of power plants.

In this reconstruction of the railroads the American Railway Engineering Association has played an active part; its organization, covering as it does the whole American continent, has been able to bring together men of a great variety of experience and to put out from time to time recommendations for the guidance of those having this work to do, based upon this experience.

That its efforts have met with success is shown by the fact that its Manual of Recommended Practice is to-day the ready reference book of all Railroad Engineers and Maintenance officials, and during the late War was so recognized by the Government, who ordered over twenty-eight hundred copies of the Manual for the use of its Railroad and Engineer officers.

The Association now has about 1400 active members, about one thousand of whom are in the employ of railroads, the balance comprising ex-railroad officials, Professors of Engineering, Consulting Engineers, and Engineers employed by companies manufacturing or handling railroad supplies.

One hundred and thirty-seven members of the Association entered the Army and Navy during the War, most of them as volunteers in the railroad and engineer regiments; two died in the service, both from disease—Captain L. V. Manspeaker died of pneumonia while in training in this country, and Lieut.-Col. Hiram J. Slifer died of the same disease contracted while in a hospital on account of injuries caused by the derailment of a motor car, while on active duty in France.

There were a number of other members of the Association that were in Government service during the War, but were not in uniform.

We have reason to be proud of the war record of the Association.

The American Railway Engineering Association has made an enviable reputation as a live, up-to-date organization, and its methods of conducting work are recognized as productive of the best results, and they are obtained largely from the fact that it is a voluntary association, its members joining because they are intensely interested in the work, and

desirous of helping to arrive at results that will benefit them in their daily duties.

We have up to this time only attempted to give recommended practice. If we could through some means insure the carrying out of these practices, great results would be secured.

The arrangement by which this Association is to work in closer connection with the American Railroad Association should assist in securing more uniform practice by the railroads who are members of that Association.

It would be a great step forward if that Association would establish standards that would be mandatory instead of recommendatory.

We have only started on the work that should be done by the American Railway Engineering Association. We have the big end of it ahead of us. We are to have a report from the Track Committee at this convention, giving recommendations for standard frogs and switches, which report has been approved by a committee of the manufacturers' association; in other words, the Engineer and the manufacturer have gotten together and agreed upon plans that combine the manufacturers' point of view, and that of the user. I hope this will lead to a more extended practice of bringing the manufacturer into the conference. It must mean greater economy in the manufacture of the article.

We, as Engineers, have been too prone to make plans without reference to shop practice. The result being unnecessary cost, with nothing to show for it.

It is to be regretted that many of the larger railroads do not follow all of the recommendations of this Association, notwithstanding the fact that the Engineers of these roads have taken an active part in perfecting such recommended practices. A campaign should be started to see if we cannot get our recommendations adopted by all of the railroads, and especially by those whose Engineers are members of the Association.

We should see what railroads there are whose Chief Engineers are not members of the Association, and make an effort to induce them to join, and to take an active interest in the work.

The Chief Engineer, as a rule, recommends the standards for maintenance of roadway and structures, and if we can get him interested in American Railway Engineering Association standards it will be an easy matter to have them adopted.

In the matter of forms for reports and records in connection with maintenance of way and structures, there is at present no uniformity of practice among the different railroads.

Our Committee on Records and Accounts has prepared certain forms for recording maintenance of way information; some are used by some railroads, but I doubt if they are all used on any railroad.

The matter of a standard set of forms for such reports is one that requires attention and following up.

I have had occasion during the past six months to try and secure

various maintenance of way information from the railroads, and have been surprised at the lack of such information in shape to be furnished readily by the majority of the roads. Upon looking into the matter I have found that the rules of accounting as issued by the Interstate Commerce Commission were prepared from an accountant's point of view, and they evidently consulted no one familiar with maintenance of way matters, the result being that they stop in their instructions before they get down to enough detail to insure such uniformity as will give a proper comparison between different railroads of the various items that would be of great value in analyzing maintenance expenditures. A study of this matter should be made by our Committee, and forms and instructions compiled that will give such information.

Much has been printed regarding details of cost of maintenance of equipment, and costs are fairly well known for certain items; but when we get below cost per mile for maintenance of way, we find nothing, and when we see the variation in accounting details, we realize that the figures given out of cost of maintenance per mile are absolutely valueless for comparison as between railroads. With maintenance of way and structures costing from 14 per cent. to 20 per cent. of the total cost of operation, there should be such records kept as will permit of greater study of detailed costs.

Of the information now called for by the Interstate Commerce Commission, little or no use is made; it is not even tabulated, and if one wants to use any of it, he has to go to the individual railroad reports filed in their office and dig it out, one railroad at a time.

There should be someone in the employ of the Commission to handle this information, who knows something about maintenance matters, and who could say what information should be secured, and who could properly analyze the information and tabulate same for the use of the railroads.

Our Committee is best qualified to handle this matter properly, and when it has reached its conclusions, we should ask the Interstate Commerce Commission to add to its instructions, so as to give the results that the Committee on Records and Accounts decide desirable. I want to emphasize the fact that Maintenance of Way and Structures has been made the tail-end of railroad operation too long, and that there is more opportunity to perfect economies in that department than in any other, for the reason that it has had no standing in court.

It has been the idea that anyone could handle *Maintenance of Way*, whether he knew anything about it or not. It has been handled along the lines of the old saying, "Let the sectionmen do it; it costs nothing to have them do it."

With the increase in the cost of labor there must be an awakening on the subject of maintenance methods. There should be a carefully worked-out maintenance program prepared by every railroad, and fol-

lowed—instead of the haphazard manner in which it is handled at the present time.

There are many things in the way of lack of uniformity in practices of railroads that should be corrected, and one of these is the rail section. The subject of a properly-designed rail section has been a live one for thirty years, it having been the subject of a study and report of a committee of the American Society of Civil Engineers, later of a committee of the American Railway Association, and it has been a subject of special study by the Rail Committee of this Association for the past ten years, and recommendations were made to, and approved by, the American Railway Association about two years ago of but seven sections between the weights of 70 lbs. and 130 lbs. per yard, and yet there are being ordered and rolled to-day about fifty different sections of rail between these weights and there are twelve different sections of 100-lb. rail being rolled. I believe that it is thoughtlessness and a lack of knowledge of this vast assortment of sections of rail that is the cause of this situation, and I hope we will all look into this matter on our respective railroads and see if we cannot get them to change to the American Railway Association standard rail sections.

There is another practice that is, if anything, more absurd and unnecessary than the variety in rail sections, and that is the variation in drilling of rail. We should all make an effort to get the drilling recommended by this Association adopted by the railroad with which we are connected. The Rail Committee this year have been investigating the vertical location; the spacing longitudinally was recommended several years ago.

Variation in drilling of rails also affects joints, making it necessary to have joints drilled differently for each railroad's needs, thus requiring them to be made to order.

With standard rail sections and uniform drilling, joints could be carried in stock by the manufacturer, and supplied as required, thus permitting them to be manufactured in bulk at odd times, the same as other standard shapes.

There is a horror on the part of the railroads of making changes, but when we consider that good practice calls for new joints on all relayer rail laid in main lines to-day, and that this rail is either sawed or rerolled, thus calling for new drilling, and when thought is given to how soon we change out all the main line rail on a division, there is nothing to prevent a change in sections being made at any time.

This variation in drilling, and much of the variation in rail sections, illustrates one of the weaknesses of the Engineer.

The word "Design" has been one of his hoodoos—to be able to say that he had "designed something" has been his one great ambition; fostered to some extent by some of the older engineering societies, who in their requisites for membership lay great stress on ability to design, and it has been with the idea that he was designing something that the Engineer has developed so many variations in rail sections and drillings.

The same thing applies to many other classes of material. There is no reason why turntables and girder spans for bridges should not be standardized for different loadings, and the shapes and angles carried in stock.

We should seek to commercialize as many articles used regularly by the railroads as possible, in order to permit their manufacture as stock articles in slack times, thus saving in the cost of manufacture, in the time required for delivery, and reducing materially the work in the drafting room.

The Engineer has been developing rapidly during the past twenty years, and to a great extent it has been due to the broadening effect of meeting and rubbing up against his fellow-engineers in such associations as the American Railway Engineering Association.

He was formerly inclined to think that he was an especially trained individual, who through that training had acquired all the knowledge there was on engineering subjects, and that between his head, his books, and his pencil he must, of course, produce the exactly correct thing.

He was inclined to feel that ability to execute, or to consider questions from a business standpoint, was non-professional, and, therefore, entirely foreign to his work.

When occasionally an Engineer broke away from this idea he was referred to, and even referred to himself, as a "practical Engineer." The very fact that to-day we seldom hear the term applied is a silent tribute to the broadening out of the Engineer as a whole. The idea also prevailed that to be an Engineer a man must be a shark in mathematics and a wizard in the laws of mechanics.

This was due probably to the fact that up to the middle of the last century colleges provided only classical or literary courses, the majority of graduates taking up law, medicine or theology; occasionally some man who was apt in mathematics or the natural sciences took up Engineering.

With the advent of schools of science and engineering came scientific courses in the older colleges, and to-day probably seventy-five per cent. of the graduates from colleges and scientific schools have taken a scientific course, and as a result, instead of mathematics and mechanics being known by few, they are common property. Therefore, they are not confined to Engineers, and to define an Engineer as one especially trained in mathematics and the laws of mechanics is a misnomer.

The events of the past four years have been the means of introducing the Engineer to the world at large, and it has discovered that, instead of being some kind of a scientific specialist, required occasionally but called upon as seldom as possible, that he is a person with real red blood, and that when Uncle Sam got into trouble, he called upon the Engineers, and lots of them, to not only start the work for him, but to furnish the sinews of war, and the skill to use those sinews, with the result that the Engineer to-day needs no introduction; the world knows him,

and he will take his proper place in the world's work. He has come out of his shell, and is in the limelight, and if he does not stay there, it is his own fault.

The events of the past four years have brought about another change that will be far-reaching, and will affect the Engineer and his work. The gathering together of nearly four million soldiers from all stations in life, and the fact that when these men were put in uniform and trained for soldiers, it was not a question of education, family connections, or financial conditions that counted, but the *man*, and when it was shown that there were equally good men measured by courage and manliness developed from one class as another, it opened the eyes of all to the fact that, measured by the standard of red blood and physical ability, class disappeared, with the result that they will all return with greater respect for mankind.

But those who, owing to environment, were laborers and obliged to put up with poor living conditions, will wonder why, having proven themselves as good soldiers, they should not share the product of their endeavors. Fortunately the man of means and education, who was associated with them as soldiers, is sure to agree with them.

The very fact that when clothed, housed and fed alike they produced the same results is proof that if paid fair wages, furnished with proper living quarters and surroundings, including good food, properly cooked and served, they will be equally good citizens. Environment is what gives a man or takes from him his self-respect. When he loses his self-respect, he loses his ambition, and with that gone, he becomes only a machine.

President Beatty, of the Canadian Pacific, in a talk to a class of student apprentices, recently stated that a man from his head down was worth two dollars and fifty cents per day, and whatever more he was worth depended upon what he had in his head. Self-respect is one of the things that is located in a man's head and makes him ambitious, and takes him out of the mere machine class.

Many of these men are handicapped by not being able to read the English language, and having little or no education in any language.

There is a popular movement under way to arrange night schools for these men, whereby they may improve themselves. It is felt that if they can be provided comfortable quarters, where they can keep clean and have a place to read or amuse themselves after work, that many will gladly take the opportunity if offered them.

This is a part of what is known as the Americanization scheme, and as so large a proportion of the floating labor element is employed on public works, and as to-day the Engineer is the one who plans all of the large industrial plants, this problem of Americanization of foreign laborers is being checked up to the Engineers.

Frances A. Kellor, assistant to Chairman, Immigration Committee, Chamber of Commerce of the United States, in an article in the Engineering News for April 12, 1917, says, "The coming executive in charge

of industrial relations management in America's great industries will be the executive with engineering training, who can handle men as well as materials. * * * The question is, will the Engineer be ready for his widening opportunity for handling men, and will the engineering colleges appreciate the demand in time to give us the necessary trained executives?"

She says, further on, "Where do we find ourselves to-day in handling labor? All the way from the ditched box-car, vermin-ridden and disease-laden, housing workmen neglected and isolated, at one end of the scale, to the Ford plant at the other."

We note that in the popular mind the treatment of maintenance of way laborers is put at the bottom of the ladder.

We have made some advances during the past two or three years toward improving this situation on the railroads. We must go at it on a much larger scale, not from a humanitarian point of view only but from a business point of view.

The high wage has come to stay, and it should be the aim of everyone to try and give as much for the high wage as can be given. Whatever is given cheerfully is as a rule a benefit to the giver, rather than an injury. What we must try to do is to improve the surroundings, the frame of mind and the physical condition of the worker, so that he gives in increased efficiency, because he wants to do so, and because he is interested in the work he is doing.

We note, also, that with the coming of the Engineer into the limelight there comes increased responsibilities, and it is up to the Engineer to accept them and show that he is able to assume them.

It is evident now that we have separated the Engineer from the barnacles to which he was attached, that he is just human, and that the qualifications for success are the same as for a banker, manufacturer, contractor or any other businessman.

He has in the past often been peeved because he was not chosen for appointment to public positions where engineering experience would be of value. With the Engineer taking the same interest in public affairs as do businessmen in general, he will be chosen for such positions. The same thing applies to executive positions on the railroads. The past few years has seen many Engineers chosen for executive offices.

Now to the young Engineers I want to say a word; don't think more about your wages than your work. When you get more interested in the salary question than in your work, you have lessoned your value, both to yourself and the railroad.

If you are not interested in your work, you are out of luck, and you had better make a change, and get into something in which you can be interested. I can imagine no greater drudgery than to be obliged to work just to put in the time and get the money at something in which a man is not interested. If all you think about is money, you had better go into the banking business. Your life is what you choose to make it—pleasant

and enjoyable, or sordid and selfish—the former if you take an interest in your work, the latter if all you think about is the size of your pay check.

Taking it for granted that you are interested in your work, and possibly have specialized on some particular part of it, I want to suggest that you do not specialize too long—a general experience is more valuable in the end.

The man that has an all-around experience is more apt to be chosen for the higher positions than the one who has specialized only on some one thing. You all want to get ahead, or you should, not for the increased salary, which is always very acceptable, but the satisfaction of knowing that you are making a success.

The requisites for success are the same in all classes of business. There are ten of them that I have in mind. They are:

Good Judgment—often termed "Horse Sense;"
Application;
Diplomacy—often referred to as "Tact;"
Executive Ability;
Nerve;
Push;
Sticktoitiveness—which means, don't be a "Quitter;"
Integrity—commonly exemplified in "Honesty" and "Fairness;"
A Thick Skin;
A Pleasant Smile.

A thick skin would save a great deal of trouble for so-called sensitive men, who imagine they are being imposed upon, when no one had any such intentions.

A pleasant smile is the password to welcome and friendship—from your superior, your equal or your inferior in rank. No one likes a grouch or a crepehanger, or wants him around if they can help it. While everyone likes to have the man around who greets him with a smile and a pleasant word.

Don't be afraid to be pleasant to the man working under you; he won't take advantage of it other than to be glad to go out of his way to do some favor to you.

There is nothing that so well defines the qualifications of the successful Engineer as the last two verses in "The Engineer's If," a parody on Kipling's "If," by Colonel Robert Isham Randolph, in which he says:

"If you can climb a stool and not feel lowly,
  Nor have your head turned by a swivel chair,
If you can reach your judgment slowly,
  And make your rulings always just and fair,
If you can give yourself and all that's in you,
  And make the others give their own best, too,
If you can handle men of brawn and sinew,
  And like the men, and make them like you, too;

* * * * * * * *

"If you can't boast a college education,
  Or, if you've got a sheepskin, can forget;
If you get a living wage for compensation,
  And give a little more than what you get;
If you can meet with triumph and disaster,
  And treat them without favor, nor with fear;
You'll be a man, and your own master,
  But, what is more, you'll be an *Engineer*."

(Applause)

The President:—The next order of business is the report of the Secretary and of the Treasurer.

Secretary E. H. Fritch presented the following reports:

REPORT OF THE SECRETARY

To the American Railway Engineering Association:

The following report on the general affairs of the Association for the past year is respectfully submitted:

Membership.

Number of members last annual report			1387
Admitted during the year		97	
Deceased	13		
Withdrawals	22	35	
Net gain for the year			62
Total Membership			1449

Members in Military Service.

One hundred and thirty-seven members of the Association were enrolled in the military service of the United States, Great Britain and the Canadian Expeditionary Forces.

Lieutenant-Colonel Hiram J. Slifer died in France, February 3, 1919.

Deceased Members.

The losses by death during the year were as follows:

James Boyd
W. A. Cowan
D. W. Cronin
C. P. Hammond
W. A. Moncure
Augustus Mordecai
Carl Stradley
John C. Nelson
John Howe Peyton
A. A. Robinson
Lieut.-Col. Hiram J. Slifer
A. Bromley Smith
A. C. Spencer

Finances.

By reference to the Financial Statement it will be noted that the Total Receipts during the calendar year ending December 31, 1918, were \$37,540.88; Disbursements, \$31,176.17; Excess of Receipts over Disbursements, \$6,364.71.

The dues of members in military service were remitted by the Board of Direction to the amount of \$1,739.00.

The Association has participated in the various war loans to the extent of \$12,000—\$11,000 being invested in United States Liberty Loans and \$1,000 in the Canadian Victory Loan.

Publications.

The usual number of Bulletins and the annual volume of the Proceedings were issued during the year.

The demand for the various publications of the Association shows a gratifying increase.

It is especially gratifying to record that the War Department of the United States Government during the year purchased 2,818 copies of the Manual of the Association for the use of the United States Army.

A liberal discount was given the Government on this large order.

Committee Reports.

Notwithstanding the unusual conditions prevailing during the year, the various committees have presented for your consideration reports of great interest and value.

Respectfully submitted,

E. H. Fritch,

Secretary.

FINANCIAL STATEMENT FOR CALENDAR YEAR ENDING DECEMBER 31, 1918

Balance on hand January 1, 1918		$30,894.48
RECEIPTS.		
Membership Account		
Entrance Fees	$ 530.00	
Dues	6,694.50	
Subscription to Bulletin	6,694.50	
Binding Proceedings and Manual	707.31	
Badges	26.00	
Sales of Publications		
Proceedings	1,089.20	
Bulletins	724.75	
Manual	8,665.83	
Specifications	88.55	
Leaflets	44.20	
General Index	1,286.75	
Advertising		
Publications	2,281.00	
Interest Account		
Investments	1,601.01	
Bank Balance	98.04	
Annual Meeting		
Sales of Dinner Tickets	786.00	
Miscellaneous	266.09	
American Railway Association		
Rail Committee	5,957.15	
Total	$37,540.88	
DISBURSEMENTS.		
Salaries	$ 6,038.00	
Proceedings	4,830.54	
Bulletins	6,983.97	
Manual	1,728.55	
General Index	26.00	
Miscellaneous Stationery and Printing	473.15	
Rents	1,165.01	
Light	26.10	
Telephone and Telegrams	125.27	
Equipment	25.80	
Supplies	286.69	
Expressage	438.32	
Postage	904.27	
Exchange	47.11	
Taxes	18.45	
Committee Expenses	100.00	
Annual Meeting Expenses	1,108.95	
Audit	100.00	
Refund of Dues Account Military Service, etc.	324.00	
War Work Campaign Contribution	250.00	
Miscellaneous	175.69	
Rail Committee	6,000.30	
Total	$31,176.17	
Excess of Receipts over Disbursements		$ 6,364.71
Balance on hand, December 31, 1918		$37,259.19

Consisting of:

Bonds	$ 35,065.65
Cash in S. T. & S. Bank	2,168.54
Petty cash in Secretary's office	25.00
	$37,259.19

STRESSES IN TRACK FUND.

Balance on hand, January 1, 1918		$2,688.97
Received from Interest during 1918		58.42
		$2,747.39
Disbursements:		
Salaries	$1,055.47	
Transportation	48.33	
Hotel and Meals	85.30	
Telephone and Telegrams	3.00	
Supplies	77.59	
Postage	10.00	
Expressage	6.35	$1,286.04
Balance on hand in Standard Trust and Savings Bank, December 31, 1918		$1,461.35

Respectfully submitted,

BOARD OF DIRECTION.

REPORT OF THE TREASURER

Balance on hand January 1, 1918		$30,894.48
Receipts during 1918	$37,540.88	
Paid out on audited vouchers during 1918	31,176.17	
Excess of Receipts over Disbursements		$ 6,364.71
Balance on hand December 31, 1918		$37,259.19

Consisting of:

Bonds	$ 35,065.65
Cash in S. T. & S. Bank	2,168.54
Petty cash in Secretary's office	25.00
	$37,259.19

STRESSES IN TRACK FUND.

Balance on hand January 1, 1918	$ 2,688.97
Received from Interest during 1918	58.42
Total	$ 2,747.39
Paid out on audited vouchers during 1918	$ 1,286.04
Balance on hand December 31, 1918	$ 1,461.35

The securities listed above are in a safety deposit box of the Merchants' Loan & Trust Safe Deposit Company, Chicago.

Respectfully submitted,

GEO. H. BREMNER,

Treasurer.

I have made an audit of the accounts of the American Railway Engineering Association for the year ending December 31, 1918, and find them in accordance with the foregoing financial statements.

CHARLES CAMPBELL,

Auditor.

GENERAL BALANCE SHEET.

December 31, 1918.

ASSETS.

	1918.	1917.
Due from Members	$2,495.35	$2,817.85
Due from Sales of Publications	1,823.94	1,421.17
Due from Advertising	400.00	440.00
Due from A. R. A. (Rail committee)	470.98	431.66
Furniture and fixtures (Cost)	997.40	997.40
Gold Badges	51.00	67.50
Publications on hand (estimated)	6,000.00	6,000.00
Extensometers	500.00	500.00
Investments	35,065.65	29,065.65
Interest on investments (accrued)	711.96	828.15
Cash in Standard Trust and Savings Bank	2,168.54	1,803.83
Petty cash Fund	25.00	25.00
Total	$50,709.82	$44,398.21

LIABILITIES.

Members' Dues paid in Advance	$2,053.50	$1,371.50
Impact Test Fund on Electrified Railways	285.46	285.46
Advertising Paid in Advance	120.00	75.00
Surplus	48,250.86	42,666.25
Total	$50,709.82	$44,398.21

The President:—Gentlemen, you have heard the report; have you any comment to make upon it? If not, it stands approved.

The next is the reports of the Standing and Special Committees. The first report is from the Committee on Signals and Interlocking, Mr. J. A. Peabody, Chairman. Will the Committee please come forward.

(For report, see pp. 327-372; discussion, pp. 807-815.)

The President:—We will now take up the report of the Committee on Signs, Fences and Crossings. Mr. Strouse, the Chairman of this Committee, is not here, and Mr. Crumpton will present the report.

(For report, see pp. 85-99; report received as information and progress.)

The President:—We will now take up Report No. XIX, on Conservation of Natural Resources, Mr. R. C. Young, Lake Superior & Ishpeming and Munising Railroads, Chairman.

(For report, see pp. 101-117; discussion, pp. 816, 817.)

The next report to be read is the report of the Track Committee. This is a pretty important report, and we rather expect a good deal of discussion on it. We have little time left before noon, so we will bring it up this afternoon as the first report. We will adjourn until two o'clock.

AFTERNOON SESSION

President Morse called the meeting to order at two o'clock.

The President:—The first business at this session will be the report of Committee V, on Track, Mr. W. P. Wiltsee, of the Norfolk & Western Railroad, Chairman.

(For report, see pp. 65-84; discussion, pp. 818-825.)

(At this point the President introduced Mr. James P. Davis, of the United States Treasury Department, who delivered a short address on "Thrift.")

The President:—The report on Records and Accounts will be presented by the Chairman, Mr. W. A. Christian, of the Bureau of Valuation, Interstate Commerce Commission.

(For report, see pp. 407-409; discussion, pp. 826-830.)

The President:—In the absence of both the Chairman and Vice-Chairman, the report on Rules and Organization will be presented by Mr. W. H. Rupp.

(For report, see pp. 749-751; discussion, p. 831.)

The President:—The report on Economics of Railway Labor will be presented to you by Mr. E. R. Lewis, Chief Engineer of the Duluth, South Shore & Atlantic Railroad. Mr. Lewis will indicate what action the Association is expected to take on the report.

(Vice-President Earl Stimson in the Chair.)

(For report, see pp. 756-804; discussion, pp. 832-836.)

EVENING SESSION

At the evening session, Mr. R. H. Ford, Principal Assistant Engineer, Chicago, Rock Island & Pacific Railroad, on behalf of the Committee on

Economics of Railway Labor, presented a series of lantern slides illustrative of the "Use of Labor Saving Devices," with brief descriptions of each device.

Mr. M. H. Wickhorst, Engineer of Tests of the Rail Committee, presented a series of lantern slides with verbal descriptions of "The Developments in the Study of Transverse Fissures."

Following the presentation of the slides, there was informal discussion of both subjects.

(The meeting adjourned to 9:30 a. m. Wednesday.)

WEDNESDAY, MARCH 19, 1919

MORNING SESSION

(Vice-President Earl Stimson in the Chair.)

Vice-President Stimson:—The report of the Committee on Wood Preservation will be submitted by the Chairman, Mr. C. M. Taylor, Superintendent of Timber Treating Plants, Philadelphia & Reading Railroad. Mr. Taylor will make the introductory statement and indicate to the convention what action should be taken in reference to this report.

(For report, see pp. 119-158; discussion, pp. 837-842.)

Vice-President Stimson:—Mr. B. H. Mann, Signal Engineer, Missouri Pacific Railroad, Chairman of the Committee on Yards and Terminals, will present the report of that Committee.

(For report, see pp. 411-430; discussion, pp. 843-853.)

Vice-President Stimson:—The report of the Committee on Electricity will be presented by the Chairman, Mr. E. B. Katte, Chief Engineer Electric Traction, New York Central Railroad.

(For report, see pp. 193-205; discussion, pp. 854-857.)

Vice-President Stimson:—The report on Ties will be presented by the Chairman of the Committee, Mr. F. R. Layng, Engineer Track, Bessemer & Lake Erie Railroad. Mr. Layng will please make the usual preliminary statement and indicate what action is to be taken on the report.

(For report, see pp. 226-238; discussion, pp. 858-863.)

Vice-President Stimson:—Professor A. N. Talbot, Chairman of the Committee on Stresses in Railroad Track, will present to you the report of that Committee and outline briefly what disposition is to be made of the report.

(For report, see pp. 215, 216; discussion, pp. 864-866.)

Vice-President Stimson:—The polls for the election of officers will close at 12:00 o'clock noon to-day. The Chair will appoint as tellers to count the votes cast, Messrs. A. M. Van Auken, Chairman; W. F. Ogle, H. H. Harsh, W. T. Dorrance, W. H. Gardner, Jr., W. L. Darden. The Secretary will turn over the ballots to the tellers at the close of this meeting and they will retire to the anteroom and be prepared to make their report before the adjournment of the afternoon session.

AFTERNOON SESSION

(Vice-President Earl Stimson in the Chair.)

Vice-President Stimson:—The report of the Committee on Buildings will be presented to you by Mr. M. A. Long, Assistant to Chief Engineer, Baltimore & Ohio Railroad. Mr. Long will make the customary introductory statement and outline briefly the action to be taken.

(For report, see pp. 207-214; discussion, pp. 867-870.)

Vice-President Stimson:—Mr. H. E. Hale, Group Engineer, Presidents' Conference Committee, Chairman of the Committee on Ballast, will indicate to the convention what action is to be taken on the report of the Ballast Committee.

(For report see, pp. 373-406; discussion, pp. 871-873.)

Vice-President Stimson:—In the absence of both the Chairman and Vice-Chairman of the Roadway Committee, Mr. W. P. Wiltsee, Assistant to Chief Engineer, Norfolk & Western Railroad, will present the report of that Committee.

(For report, see pp. 159-192; discussion, pp. 874-881.)

Vice-President Stimson:—The report of the Rail Committee will be submitted to you by the Chairman, Mr. G. J. Ray, Engineering Assistant to Regional Director, United States Railroad Administration.

(For report, see pp. 445-647; discussion, pp. 881-888.)

Vice-President Stimson:—The Tellers appointed at the morning session have filed their report, and the Secretary will read it.

Secretary Fritch read the following report of the Tellers:

REPORT OF TELLERS

To the American Railway Engineering Association:

Your Tellers, appointed to canvass the votes cast for officers of the Association for the ensuing year, report as follows:

President:

Earl Stimson	638 votes
C. F. Loweth	1 vote

Vice-President:

J. A. Atwood	633 votes
C. E. Lindsay	4 votes
L. A. Downs	1 vote

Treasurer:

George H. Bremner	631 votes
R. H. Ford	1 vote

Secretary:

E. H. Fritch	634 votes

Directors (Three to Be Elected):

C. F. Loweth	365 votes
F. L. Thompson	280 votes
Hadley Baldwin	256 votes
H. T. Porter	218 votes
F. E. Turneaure	198 votes

E. B. Temple	180 votes
Geo. A. Mountain	171 votes
J. C. Mock	119 votes
J. A. Peabody	94 votes
W. M. Dawley	1 vote
E. R. Lewis	1 vote

Nominating Committee (Five to Be Elected):

C. F. W. Felt	458 votes
G. J. Ray	449 votes
J. R. W. Ambrose	342 votes
D. J. Brumley	310 votes
H. E. Hale	305 votes
A. W. Newton	302 votes
Maurice Coburn	279 votes
E. A. Hadley	229 votes
Louis Yager	177 votes
W. L. Darden	1 vote
A. L. Grandy	1 vote
H. N. Rodenbaugh	1 vote

Respectfully submitted,

A. M. Van Auken, *Chairman;*
W. L. Darden,
W. T. Dorrance,
W. H. Gardner, Jr.,
H. H. Harsh,
W. F. Ogle, *Tellers.*

(The meeting adjourned to 9:30 a. m. Thursday.)

THURSDAY, MARCH 20, 1919

MORNING SESSION

(Vice-President Earl Stimson in the Chair.)

Vice-President Stimson:—The first business this morning is the consideration of the report of the Committee on Iron and Steel Structures. The report will be presented to you by the Chairman, Mr. O. E. Selby, Principal Assistant Engineer, Cleveland, Cincinnati, Chicago & St. Louis Railroad.

(For report, see pp. 649-694; discussion, pp. 889-902.)

Vice-President Stimson:—The next report to be considered is that of the Committee on Masonry. Mr. F. L. Thompson, Chief Engineer of the Illinois Central Railroad, Chairman of the Committee, will present the report. Mr. Thompson will make the customary introductory statement.

(For report, see pp. 695-748; discussion, pp. 903-908.)

Vice-President Stimson:—Mr. A. F. Dorley, Engineer Maintenance, Missouri Pacific Railroad, Chairman of the Committee on Water Service, will present the report of that Committee and indicate what action is to be taken.

(For report, see pp. 277-326; discussion, pp. 909-911.)

AFTERNOON SESSION

(Vice-President H. R. Safford in the Chair.)

Vice-President Safford:—The report of the Committee on Wooden Bridges and Trestles will be submitted to you by the Chairman, Mr. W. H. Hoyt, Assistant Chief Engineer, Duluth, Missabe & Northern Railroad.

(For report, see pp. 239-275; discussion, pp. 912, 913.)

Vice-President Safford:—Mr. E. H. Lee, President of the Chicago & Western Indiana Railroad, Chairman of the Committee on Uniform General Contract Forms, will indicate to you what disposition is to be made of the report of that Committee.

(For report, see pp. 217-225; discussion, pp. 914, 915.)

Vice-President Safford:—The next report to be considered is that of the Committee on Economics of Railway Operation. The report will be presented by Col. F. W. Green, Chairman. Col. Green has been "over there" and has just returned to this country. We doubly welcome him. (Applause.)

(For report, see pp. 431-443; discussion, pp. 916-918.)

Vice-President Safford:—The Chair will impose on the good nature of Col. Green by asking him if he will not give us a few minutes' talk on the observations which he was able to make in his service abroad.

Col. F. W. Green:—Mr. Chairman and Gentlemen:—I went over as Captain of the Twelfth Engineers. We left New York on July 28th and arrived at Liverpool August 12, 1917. We went to a camp in Southern England, where we remained three days, and marched through the streets of London on August 15th. That was the first time that any armed troops, under a foreign flag, had marched through the streets of London since the time of William the Conqueror, in 1066. Much was made of that fact by some of the historians. There were several regiments of Engineers. I was in the first regiment behind the band. I happened to have Company A and the impressions I received on that march I will never forget.

It will be recalled at that time, which was immediately following the capture of the Chemin de Dames by the Germans, where Gen. Neville suffered casualties amounting to 180,000 men, that the morale of both the French and English nations was at a very low ebb. We discovered later on that we were marching through London for the purpose of upbuilding and strengthening the morale of the English people. I saw some sad sights there. On numberless occasions I saw old men with tears streaming down their faces and giving us a most pathetic, but nevertheless hearty, welcome. An old lady came up to me—evidently she was a person in rather straightened circumstances—and told me she had lost seven sons, who were now sleeping under the poppies in Flanders, and she had one more son to give, and he was then in service, and she

was willing to give him if Germany could be beaten. That seemed to be the situation throughout England.

When we got to France we found the French in the same mood—that cold, stern determination to fight it out. They felt that the United States had gotten into the war too late, but nevertheless they were determined to fight it out, and said they would fight until the last man was killed, and then, everybody being killed, they would avoid the humiliation of a surrender to the Germans. They felt that way and you could feel it in the atmosphere. They felt that way and you could feel it also.

Later on when we got better acquainted with our English friends they told us we had gotten into the war too late to be of any real benefit.

I was at the front for only ten weeks, and others who have been there longer can give you perhaps a much more intelligent account of what took place there. Service at the front is very interesting and fascinating, something that I do not believe anyone would ever forget. I think it makes a man a better man to have served at the front—to have seen this splendid spirit of sacrifice and of devotion to a common cause.

At the end of ten weeks I was transferred to the Transportation Department, because I had some transportation experience, and sent down to open up the Port of Brest. I was the first U. S. Army officer at the Port of Brest assigned there under army orders. The Port of Brest was decided on as a port of debarkation, not because of its climate, but solely because it was the only deep-water harbor in France where vessels like the Leviathan, the Olympic, the Aquitania, the George Washington, the Mt. Vernon, and vessels of that character, could find sufficient depth of water.

Other boards had been sent to Brest to reconnoiter the situation and each recommended adversely against Brest. I happened to be a member of the Fourth Board, and we decided that we would make a similar recommendation, but temper it with the statement that if the exigencies of the situation became so imperative as to require the use of Brest, that it could be used, but it would never be convenient or comfortable from the standpoint of the men who arrived and left on ships there. The climate is bad—it rains about 313 days in the year. There is lots of mud, the rest camp is about three miles away from the dock, and the prevailing winds are southwesterly, the humidity is great and Brest is not a comfortable place.

Incidentally, I may say that, in my opinion, this is the cause of so much complaint that you have read in the papers lately about Brest. Its climatic conditions are bad. While the Army has done what could be done in the circumstances to make the port as comfortable as possible, it is not wholly comfortable and never will be, because of the climatic limitations of which I speak.

After being at Brest for eight months I was transferred to St. Nazaire, the largest cargo port in the A. E. F. It has handled more heavy tonnage than any other port. We unloaded a total of 1,389

locomotives there. There is very little else of interest in connection with the operations at St. Nazaire, except that the work was arduous and unremitting.

We succeeded on the day of the armistice not only in having enough subsistence and supplies to take care of the Army of two million men who were there, but we had a 90-day supply in storage at the warehouses in the base ports, and the warehouses in the intermediate and advance sections. That was considered rather surprising by our Allies—they thought the ship situation was so desperate that we would be hampered on account of a shortage of ships, but instead of the ships being the limiting factor, it became the French railroads.

The French railroads, roughly speaking, were able to take about one-third of the tonnage which we were able to discharge from the ships into the interior of France. Towards the last the limiting factor was not the ship situation—the bridge of ships, as the expression was—but the inability of the French railways to handle the tonnage, and as the Germans retired the lines of communications of the Allies became longer and this, of course, increased the length of the haul, and gradually the transportation situation became worse instead of better, notwithstanding the fact that the Transportation Department of the A. E. F. had anticipated that situation and had put into the common pool of cars about 70 new U. S. A. cars per day, and they had contributed some 1,400 locomotives.

It is rather difficult to describe in a few minutes just what the problem was over there—the conditions were so entirely different that it cannot be described in a few words, but it was the largest enterprise I ever had any connection with, and, in fact, it surprised all of us who were privileged to take part in it to see how it developed, how it grew, and how it became orderly from the original chaos and disorder which always characterizes a new operation starting out with new men with diverse thoughts and strange experiences.

Just a word as to the Engineers. Notwithstanding the romance and glamour which has characterized the descriptions by some of our magazine writers as to the war, the French and British General Staff officers, with some of whom I came in contact in my relations with the work, have always stressed the fact that this war was an "Engineers' War," and I am inclined to believe that is true. Everywhere where anything important was to be done, was to be planned or to be executed, it was always found that the Engineers were called upon to meet the situation, and I am sure you will be glad to know that the Engineers somehow and in some way always met the situation and solved it.

The French and the British were very high in their praise of the work done by all of our Engineering organizations, and I want to take this occasion to say that I have the very highest and most profound regard and admiration for the ability of both the French and British Engineers. They approach their problems a little differently from the manner in which we approach ours. They are more particular and perhaps a

little more roundabout in making designs. Nevertheless, they get the same results. They are superior to us in many ways, I think, in planning and we are superior to them in many ways in execution.

I think all the American Engineers, and we have a good many of them who stood rather high in the Engineering profession in the States, who were over there, and with whom I have talked, have felt that their experience in comparing notes and by rubbing up against the French and British Engineers has been very helpful to them and that they have been very much aided and developed by the experience.

There is another thing which may seem strange to you. In my talks with the French Engineers—my work brought me in almost daily contact with some of them, especially those of the Pons et Chaussées—I used to ask them if they read any Engineering literature published in America, and I never found one who was not a regular reader of the Proceedings of the American Railway Engineering Association. In their estimation the American Railway Engineering Association is the outstanding and prominent Engineering Association in the United States.

I asked them if they did not read the proceedings of the American Society of Civil Engineers or the American Society of Mechanical Engineers, or the other Engineering Societies. They said that they received these, but for some reason or other the publications of the American Railway Engineering Association seemed to contain matter which had been more thoroughly considered and was of a less controversial character than the matter in some of the other proceedings.

I come back to the United States prouder of my membership in the American Railway Engineering Association than I ever was before. I think that is about all I have to say. (Applause.)

Vice-President Safford:—In the absence of the Chairman, the report of the Committee on Economics of Railway Location will be presented by the Vice-Chairman, Mr. C. P. Howard, of the Bureau of Valuation, Interstate Commerce Commission.

(For report, see pp. 752-755; discussion, pp. 919-923.)

Vice-President Safford:—The reports of Standing and Special Committees having been disposed of, the next order of business is "New Business." Has any member anything to offer under the heading of "New Business?"

Mr. C. E. Lindsay (U. S. R. A.):—Mr. Chairman, I have the following resolution to offer:

"RESOLVED, That the members of the American Railway Engineering Association, in convention assembled, desire to place on record their appreciation of the admirable manner in which this convention has been presided over by Mr. C. A. Morse, and for the efficient administration of the affairs of the Association during his occupancy of the presidential chair.

"RESOLVED, That a copy of this resolution be spread on the Minutes of this meeting and an engrossed copy be presented to Mr. Morse."

(The resolution was put to vote and carried unanimously.)

Mr. Lindsay:—I offer the following resolution:

"RESOLVED, That we deplore the absence, by reason of illness, of our beloved President from some sessions of our convention.

"RESOLVED, That we express to him and his wife our great sympathy and our heartfelt hope for his speedy and complete recovery and return to our fellowship and service."

(The resolution was put to vote and carried unanimously.)

Mr. E. A. Frink (Seaboard Air Line):—Mr. Chairman, I desire to offer the following resolutions:

"RESOLVED, By the American Railway Engineering Association, in convention assembled, that its thanks are hereby extended to—

"Hon. Atlee Pomerene, Rev. George Adam and Robert J. Cary, Esq., for their excellent addresses at the Annual Dinner on the evening of March 19th.

"To the Chairmen, Vice-Chairmen, and members of the several Committees for their labors during the past year and for valuable reports presented to the meeting.

"To the Committee on Arrangements for the splendid manner in which the arrangements for this convention have been carried out.

"To the Technical Press for courtesies extended during the year and also during the convention.

"To the National Railway Appliances Association for the comprehensive and instructive exhibit of railway devices used in the construction, operation and maintenance of railways."

(The resolution was put to vote and carried unanimously.)

Mr. W. D. Faucette (Seaboard Air Line):—Mr. Chairman, the question was asked here on the first day of the convention by the President as to how many members had read these Committee reports, and the answers regarding the one under discussion were almost unanimous that it had not been read or had been little read.

During the war period there is no doubt that it has been very difficult to get these reports in the hands of the Secretary promptly, but it seems to me that it would be of the greatest measure of benefit to all the membership if we could get these reports printed and in the hands of the members in sufficient time to read and analyze them. There are several hundred pages of technical matter involved, and this reading is not casual—considerable of it is technical. If we want to get the benefit of the committee-work, and have live discussions, the members must have time to read these Bulletins carefully.

In my case, and I do not know how many members have had the same experience this year, but I received one copy about four weeks ago, two copies about 48 hours before I left Norfolk, and the last copy I never did receive before reaching Chicago. It seems to me that those who have the giving of directions in this matter this year might well insist on the committees bringing in their reports in time for submission in print to the several members for their careful reading.

In the General Rules for the publication of these reports, it is stated in paragraph 9, as follows:

"9. Committee reports to come before the succeeding convention for discussion should be filed with the Secretary not later than November 30th of each year."

While I presume the committees this past year did the best they could, it is to be observed that a great many of these reports bear date subsequent to January 1, 1919. I only mention this because I know in my own case, if I got these reports at least 40 days before the March meeting it would be of great benefit to me, and I believe likewise to others.

Vice-President Safford:—As there is no further new business, the Secretary will read the result of the election of officers.

Secretary Fritch:—The result of the election of officers for the ensuing year is as follows:

President—Earl Stimson.

First Vice-President—H. R. Safford.

Second Vice-President—J. A. Atwood.

Secretary—E. H. Fritch.

Treasurer—George H. Bremner.

Directors—C. F. Loweth, Hadley Baldwin, F. L. Thompson.

Members Nominating Committee—C. F. W. Felt, G. J. Ray, J. R. W. Ambrose, H. E. Hale, D. J. Brumley.

Vice-President Safford:—The Chair will appoint Mr. Sullivan and Mr. Lindsay to escort the President-Elect to the platform. (Applause.)

Vice-President Safford:—Mr. Stimson, I feel it an honor, in the absence of President Morse—because it is an honor to represent in this capacity a man who, by reason of illness, is not able to be present, but whom we admire so much—I feel it a double pleasure because I am tendering the office of President to you as a very warm friend, and I know I speak the voice of the entire body when I say that we feel you are well fitted to take up the responsibility of this office. I warn you that you are following a line of splendid men who have held this office. You are taking the office at a time which I believe is probably the most interesting that has ever confronted this body, but we have no doubt of your ability to carry us through and you may be sure we stand ready to help you in all ways and at all times. (Applause.)

President-Elect Stimson:—Gentlemen: I regret the unfortunate circumstance that made it necessary for Mr. Safford to perform the installation ceremony. We all do. I will have the happy privilege next year of returning the courtesies of Mr. Safford. I will remember all the kind words said to me, and I will make the most of my opportunity to repay him in full and with interest, and it will be a very pleasant and a very easy thing to do.

The work that faces this Association is greater probably than that which has confronted us in any other year. We have assumed responsibilities and obligations to the American Railroad Assoociation with which we have become affiliated in our great work of Railway Engineering and Maintenance.

I wish to request that all the committee chairmen get after their work early this season. The personnel of the committees will go out within a few days, and as soon as the Chairman receives his assignment and the list of his committeemen, I hope he will call a meeting of his committee and organize for the work of the committee and prosecute it vigorously.

While I think the work done by these committees this year has been very good, it will not go next year. We must do better. We have had interesting reports. However, some of the committees have not made reports of constructive value and subjects have been referred back to the committees for further consideration. I am sure that the Association I have mentioned will not be so lenient. In fact, the tip has been given to me that they want what they want when they want it, and that when that Association gives us something to do we must go ahead without delay and submit a definite and conclusive report.

I appreciate highly the honor you have conferred on me in electing me President of your Association, which I consider the highest honor that the railway engineering profession has within its gift. With your help, which I know I have, I intend to make my administration measure somewhat up to the very high standard set by my predecessors. (Applause.)

President Stimson:—If there is no further business, the Twentieth Annual Convention will stand adjourned *sine die*.

The Twenty-first Annual Convention of the American Railway Engineering Association will be held at the Congress Hotel, Chicago, March 16, 17 and 18, 1920.

E. H. Fritch,
Secretary.

COMMITTEE REPORTS

REPORT OF COMMITTEE V—ON TRACK.

W. P. Wiltsee, *Chairman;*	H. A. Lloyd,
M. C. Blanchard,	J. R. Leighty,
Geo. H. Bremner,	F. H. McGuigan, Jr.,
Garrett Davis,	J. V. Neubert,
P. D. Fitzpatrick,	R. M. Pearce,
G. W. Hegel,	H. T. Porter,
T. H. Hickey,	J. H. Reinholdt,
T. T. Irving,	E. M. Rhodes,
J. B. Jenkins,	J. B. Strong,

Committee.

To the American Railway Engineering Association:

Your Committee on Track respectfully submits its report to the Twentieth Annual Convention.

The following subjects were assigned your Committee by the Board of Direction:

1. Make critical examination of the subject-matter in the Manual, and submit definite recommendations for changes, giving special attention to specifications for tie-plates.
2. Report on typical plans of turnouts, crossovers, slip-switches and double crossovers, and prepare detail plans for such work, including such incidentals as tie-plates, rail braces, riser plates, etc., conferring with Committee on Signals and Interlocking.
3. Report on reduction of taper of tread of wheel to 1 in 38 and on canting the rail inward.
4. Report on test of tie-plates subject to brine drippings.
5. Report on specifications for relayer rail for various uses.
6. Consider the advisability of reducing allowable flat spots on freight car wheels, collecting data as to damage done by flat spots.
7. Report upon the effect of fast trains upon the cost of maintenance of way and equipment.

COMMITTEE MEETINGS.

Meetings of the whole Committee were held in Chicago on June 6 and September 19, and in Cincinnati on December 9, in addition to the meetings held by the various Sub-Committees. The meeting held in Chicago on September 19, as well as several meetings of Sub-Committee No. 2, were joint meetings with the Standardization Committee of the Manganese Track Society.

(1) REVISION OF MANUAL.

In Appendix A attention is called to a number of changes in the Manual that the adoption of the plans submitted under Subject No. 2 will necessitate. It is not thought desirable to make definite recommendations as to these changes until after the adoption of the plans.

(2) TYPICAL PLANS OF TURNOUTS, CROSSOVERS, SLIP-SWITCHES AND DOUBLE CROSSOVERS AND DETAIL PLANS FOR SUCH WORK.

In Appendix B the Committee submits detail plans as per instructions and recommends their adoption under the heading of "Conclusions." These plans are the result of the study and the coöperation of your Committee and the Switch and Frog Manufacturers of the Manganese Track Society.

(3) REDUCTION OF TAPER OF TREAD OF WHEEL TO 1 IN 38 AND ON CANTING THE RAIL INWARD.

In Appendix C the Committee reports on this subject and submits the matter as information, in addition to the report the Committee made on the same subject and printed in the Proceedings of 1918.

(4) TEST OF TIE-PLATES SUBJECT TO BRINE DRIPPINGS.

The Committee has continued its investigations, but on account of the unsettled conditions during the past year has been unable to obtain reliable data in connection with its tests now being made on the tracks of the Chicago Junction Railway at Chicago. The Committee expects to start new tests during the current year.

(5) SPECIFICATIONS FOR RELAYER RAIL FOR VARIOUS USES.

The Committee has prepared a specification for relayer rail for various uses, but it is not ready for submitting to the Association. Therefore the Committee can only report progress on this subject.

(6) REDUCING ALLOWABLE FLAT SPOTS ON FREIGHT CAR WHEELS.

In Appendix D the Committee reports on this subject, and recommends that the report be received as information and referred to the Master Car Builders' Association with the recommendation that the allowable limit of flat spots be fixed at 1½ inches.

(7) EFFECT OF FAST TRAINS UPON COST OF MAINTENANCE OF WAY AND EQUIPMENT.

The Committee can only report progress on this subject.

CONCLUSIONS.

Your Committee makes the following definite recommendations to the Association:

Received as Progress Report.

Subject (3) Report on reduction of taper of tread of wheel to 1 in 38 and on canting rail inward.

For Adoption and Publication in Manual.

Subject (2) Plans for frogs and switches, as follows:

Plan No. 101—16′ 6″ split-switch with uniform risers.
Plan No. 102—16′ 6″ split-switch with graduated risers.
Plan No. 103—11′ 0″ split-switch with uniform risers.
Plan No. 104—11′ 0″ split-switch with graduated risers.
Plan No. 201—Details of split-switch fixtures (General).
Plan No. 202—Details of split-switch fixtures (Special features).
Plan No. 203—Detail of split-switch fixtures, heel plates and turn-out plates.
Plan No. 210—Illustration bills of material for 11′ 0″, and 16′ 6″ split-switches, in accordance with plans Nos. 101, 102, 103 and 104.
Plan No. 301—No. 6 rigid frog.
Plan No. 302—No. 7 rigid frog.
Plan No. 303—No. 8 rigid frog.
Plan No. 304—No. 10 rigid frog.
Plan No. 401—No. 10 spring rail frog.

Accept as Information.

Subject (6) Report upon the advisability of reducing allowable flat spots on freight car wheels.

RECOMMENDATIONS FOR FUTURE WORK.

Your Committee recommends for next year's work:

Continuation of Subjects (1), (2), (3), (4), (5), (7), with the addition to Subject (2) of typical plans of crossings, with detail plans of such work.

Respectfully submitted,

THE COMMITTEE ON TRACK.

Appendix A.

(1) REVISION OF MANUAL.

With the adoption of the plans shown in Appendix B, it will be necessary to make the following revisions in the 1915 Manual:

The plans on pp. 169, 170 and 171 will be eliminated.

The specifications for frogs, crossings and switches, pp. 172 to 181, will need revisions in paragraphs 10, 11, 18, 38, 43, 48, 52, 53, 61 and 62.

The most important of these changes are, in throw of switch, tie spacing at heel of joint, angle of planing chamfer cut, size of switch rods, length of No. 6 and No. 8 rigid frogs, and material of fillers, riser blocks and spring covers.

The revision of the tie-plate specifications was carefully considered in connection with the specifications now being prepared by the American Society for Testing Materials, but as that tentative specification has again been revised, it was thought advisable to delay this matter and recommend that the next Committee consider these specifications as well as other specifications in the Manual in connection with the Committee of the American Society for Testing Materials, and if possible decide on a specification that has the approval of both associations.

(2) TYPICAL PLANS OF TURNOUTS, CROSSOVERS, SLIP-SWITCHES AND DOUBLE CROSSOVERS, WITH DETAIL PLANS FOR SUCH WORK, INCLUDING SUCH INCIDENTALS AS TIE PLATES, RAIL BRACES, RISER PLATES, ETC.

Your Committee submits herewith the following detail plans, with recommendations for adoption:

Plan No. 101—16′ 6″ split-switch with uniform risers.
Plan No. 102—16′ 6″ split-switch with graduated risers.
Plan No. 103—11′ 0″ split-switch with uniform risers.
Plan No. 104—11′ 0″ split-switch with graduated risers.
Plan No. 201—Details of split-switch fixtures (General).
Plan No. 202—Details of split-switch fixtures (Special Features).
Plan No. 203—Details of split-switch fixtures, heel plates and turnout plates.
Plan No. 210—Illustration bills of material for 11′ 0″ and 16′ 6″ split-switches, in accordance with plans Nos. 101, 102, 103 and 104.
Plan No. 301—No. 6 rigid frog.
Plan No. 302—No. 7 rigid frog.
Plan No. 303—No. 8 rigid frog.
Plan No. 304—No. 10 rigid frog.
Plan No. 305—Details of plates for Nos. 6, 7, 8 and 10 rigid frogs.
Plan No. 401—No. 10 spring rail frog.

The plans will be found complete for carbon rail 11′ 0″ and 16′ 6″ switches and for carbon rail frogs as used with switches of these lengths. The plans were made for 100-lb. rail, but the plans and specifications will apply for any standard rail section weighing 80 lbs. or over. The details illustrated have been based on:

(1) 1915 Manual.
(2) Plans published in Bulletin 202 by this Committee as a progress report, and on criticisms received on these plans.
(3) Recommendations of the Switch and Frog Manufacturers of the Manganese Track Society.

It will be found that the plans as now submitted are much wider in scope than those published in Bulletin 202; some revisions have been made and additional details are offered to more fully cover a wider variety of traffic conditions. No patented features have been specified, and all details shown are recommended as being good practice established by use in service on the railroads of America. Where alternates are detailed the parts have been made interchangeable in so far as possible

by giving the essential dimensions. All alternates detailed are in extensive use by preference in some parts of this country.

The plans as submitted have the approval of both your Track Committee and the Switch and Frog Manufacturers of the Manganese Track Society, who very kindly prepared the drawings in accordance with the desires of the Sub-Committee. If these plans are approved by the Association, it is recommended that further plans be prepared along similar lines for longer switches and larger numbered frogs; also layout plans embodying these fixures for turnouts, crossovers, slip-switches and double crossovers.

It has been found that there are in use at the present time not only a great variety of styles of switch fittings, but a variety of dimensions for the same style of fittings used on the railroads of America. The adoption of these plans will not only make the dimensions uniform for the same style of fittings, but will make the different styles of fittings largely interchangeable.

Split-Switches.

BILLS OF MATERIAL for switches to meet different traffic conditions can be made up as illustrated on plan 210. The layout plans of switches, Nos. 101, 102, 103 and 104, detail the planing, tie spacing and general arrangement, but do not specify the detail sizes of the fixtures. The split-switch fixtures are detailed on plans Nos. 201, 202 and 203.

The Committee on Signals and Interlocking has suggested a change in drilling of the first holes in the switch point to read 2½" by 5" by 5" by 5", but after a conference we were advised that the Committee on Signals and Interlocking is not unanimous on this question and can work to the present drilling, which is better suited to hand-thrown switches, and the interlocking detals can be worked with the present drilling satisfactorily; so our Committee has decided not to recommend any change in the spacing of holes from the end of the rail specified in the present Manual on page 179. The height of the holes, however, is not specified in the Manual. A height of 1¼" above base of rail measured on the face of reinforcing bar is recommended (see section, detail No. 2000, on switch plans), so that the height may be uniform and the switch clips interchangeable.

SWITCH PLATES are detailed in two widths, 6" width and 7" width; the riser plates in two styles, solid base riser plates and pressed riser plates. In the 6" width the pressed riser plates are shown of ⅝" by 6" stock; the solid base riser plates of ½" by 6" stock, under base of stock rail; the 7" width of ¾" by 7" stock. The 7" width as specified in the 1915 Manual is recommended for congested traffic conditions, but the lighter 6" width is desirable for use where there are less congested traffic conditions. The switch plates, in any case, being longer than standard tie plates as used for tangent track, should preferably be of heavier sec-

tion. This should be taken into consideration in making up bills of material, especially for tie-plated turnouts.

Switch Rods as specified in the 1915 Manual are recommended of rigid style when the throwing fixtures are provided with adjustment for wear and other causes. However, as there are a large number of throwing fixtures in use that do not provide these adjustments, three details of adjustable switch rods and clips are illustrated. The drilling in the switch points being the same, any of the switch rod and clip details can be applied.

Two Styles of Split Switches are Shown, one of uniform risers and one with graduated risers. For tie-plated turnouts, where equivalent plates and fixtures are used, the weight of material is approximately the same for the two styles of switches.

Split-Switch with Uniform Risers, as illustrated on plan No. 101, is a development of the 16′ 6″ switch shown on page 178 in the 1915 Manual. The elevation of the switch rail is run off in the lead rails. The heel plates have been detailed not only to provide for the run-off of the switch elevation, but also for shoulders for both the lead rails and the stock rails. A variable tie spacing is given so that the same detail of plates will apply to turnouts No. 7 to 10 inclusive.

This construction provides shoulder tie plates from the heel of the switch back to where there is sufficient spread to permit the use of standard shoulder tie plates. With this style of switch the splice bars may be bolted up tight, and the play between the shoulders back of the switch heel allows sufficient flexibility for the throw of the switch.

Split-Switch with Graduated Risers. Plan No. 102 details a 16′ 6″ split-switch with vertical bend in the switch rail so that the heel joint is level with the stock rail. A heel block is illustrated with the bolts tightened on pipe thimbles, permitting a hinge motion for the throw of the switch. With this style of switch, the heel joint being level, additional heel or turnout plates are not required except when further tie plating is desired, as in a tie-plated turnout. Also, with this style of switch the equipment can be cut down to a minimum by omitting the heel block and heel plates for a cheaper switch for emergency or light traffic requirements. In this connection the detail of switch as adopted by the United States War Department for the United States railways in France is illustrated by Specification F on Plan No. 210.

Rigid Frogs.

One style of rigid frog is detailed on Plans No. 301, 302, 303 and 304 for Nos. 6, 7, 8 and 10 frogs, in which the flare in the wing rail is machined from the head of the rail. This is recommended in preference to the bent flare, as it allows the use of shorter bolts and more rigid construction.

The detail of point planing conforms to the 1915 Manual.

The diameter of the bolts is specified to vary according to the height of the rail.

Two approved methods of plating are illustrated on Plan No. 305. The shorter three-tie base plate with tie plates beyond is recommended rather than the long base plate as illustrated in the 1915 Manual. For well-ballasted track individual tie plates throughout are recommended as good practice.

Spring Rail Frogs.

The spring rail frog is not customarily used except on the main line. A No. 10 frog is detailed on Plan No. 401 to go with 16′ 6″ switch. The details, however, will apply in general to frogs Nos. 8 and 11.

General Notes.

The throw of the switch is specified 4¾ inches on the center line of switch rod No. 1. This will make the throw at the point approximately 5 inches in practice, or, theoretically, 4$\frac{11}{16}$ inches at the point of 16′ 6″ switch.

The tie spacing at heel joint for the switches is shown 18 inches, which is to be recommended rather than the wider spacing shown on the plans in the 1915 Manual.

The angle of planing chamfer cut, section No. 2000, is specified 78 deg., as the 70-deg. angle specified on page 179 in the 1915 Manual is generally considered too abrupt and is not in common use.

The switch rods are specified in two sizes, 1″ x 2½″ and ¾″ x 2½″, as the ¾″ x 2½″ rods, as specified on page 180 in the 1915 Manual, are considered too light to meet heavy congested traffic conditions.

The No. 8 rigid frog has been detailed 13′ 0″ long, instead of 13′ 6″ long, as specified on page 184 in the 1915 Manual, so that it may be substantially built and cut from 33′ 0″ rails. The 6 inches difference in length is made on the heel end of the frog, and will not interfere with theoretical alinement data for the lead.

The No. 6 rigid frog has been detailed 10′ 0″ long, as this length provides ample room for splice bars. A longer frog is considered objectionable for a sharp turnout.

The plans now being offered are complete in themselves and give much fuller detail than plans previously published. It is intended that if the plans submitted meet the general approval, the Committee will prepare plans for other angle frogs, switches, turnouts, crossovers and slip-switches for presentation at the next convention.

It will be noted that the frogs recommended in the Manual are 8, 11 and 16. While the Committee is not reconsidering this recommendation, it is their intention to submit, as well as plans for frogs of those angles, also plans of Nos. 6, 7, 10 and 20 rigid frogs and No. 10 spring frog, as there is considerable demand for frogs of these numbers.

Appendix C.

(3) REPORT ON REDUCTION OF TAPER OF TREAD OF WHEEL TO 1 IN 38 AND ON CANTING THE RAIL INWARD.

Prior to 1878 the amount of coning in car and engine wheel varied. At that time, a ratio of 1 in 38 was adopted by the Master Car Builders' Association and this remained standard until 1907, when the Association revised the taper to 1 in 20, the present standard. Twenty-six railroads in the United States and Canada have reported to your Committee on this subject and twenty-two of the twenty-six state that the standard coning of 1 in 20 is used on all their equipment. Two roads use a coning of 1 in 38 on all steel and steel-tired wheels and 1 in 20 coning on cast-iron wheels. One road uses a coning of 1 in 38 on all equipment. Another using a coning of 1 in 20 states that they are about to change to 1 in 38. One road uses no taper on engine and tender wheels and a taper of 1 in 20 on passenger and freight equipment. Attached is a statement entitled "Taper of tread of wheels used by various railroads and their recommendations as to changing same."

Experience has shown that a certain amount of taper of tread of wheels is necessary to reduce rubbing or slipping friction between wheel and rail which is the cause of loss of metal from flange and tread of wheel and from rail, instead of from rolling contact. For economical wearing to both wheel and rail, the wheel must roll on the rail with the least amount of rubbing and slipping and the wheel travel parallel to the rail. The coning of the wheel and the contour of the head of rail must give the proper contact to provide the least amount of sliding friction.

In the past it has been the general practice of the railroads to place the vertical axis of the rail perpendicular to the plane of the track. However, some roads have deviated from this practice, as will be explained later, and canted the rail inward. With the standard Master Car Builders' wheel taper of 1 in 20 and the vertical axis of rail at right angles to the plane of track, the point of contact with the rail of A. R. A. section and 14-inch top radius is 45/64 inches inside of center of rail toward gage side and for wheels having 1 in 38 taper and the same section of rail, the point of contact is 23/64-in. inside of center of rail.

The Proceedings of the Master Car Builders' Association, Vol. 150, Part 1, page 189, for 1916, states as follows concerning wheel tapers:

"A flange thicker than the present standard has some distinct disadvantages. One of the strongest arguments offered for the adoption of the present taper of tread of 1 in 20 was the opportunity afforded a pair of wheels to move laterally until both run upon a common diameter, this condition tending to keep flanges away from the rail, thereby not only decreasing the flange and rail wear, but train resistance as well. Unless the whole track structure is changed, a thicker flange would reduce or eliminate entirely this opportunity for lateral motion."

There are also several disadvantages of heavy coning, one being that the surface of rail gradually wears to an inclined surface similar to cone of wheel. In this condition, the abrasion of metal and slippage resistance is considerably increased.

Below is a report of Dr. P. H. Dudley, Consulting Engineer on Rails, Tires and Structural Steel, New York Central Lines, of August 30, 1918:

"Your letter of July 26, in reference to the reduction of the present treads of wheels to 1 in 38, was received at the office during my absence. The question is of more importance than generally realized by railroad officials, and I am always pleased to help state some of the general facts for consideration.

"The railroads in the United States and British North America carry the heaviest wheel loads of any railroads in the world, yet have unadvisedly accepted contours for their wheel treads used by the foreign railways for much lighter wheel loads and trains.

"I have been over the European railways on three different trips to study their rails, equipment and the reciprocal wear of each. The contours of their wheel treads have an inclination of 1 in 20 for about one-half of the width of the tread, and then a chamfer of increased inclination for the rest of the tread, but the outside did not touch the outer corner of the rail heads on curves even with their rails inclined 1 in 20, held in cast-iron chairs. The rail heads were worn down on gage side. The contour of the wheel tread is similar to Fig. 33, page 45, Report No. 69 to the Rail Committee of the American Railway Engineering Association.

"Such a contour does not cover the entire width of the bearing surface of our rails, but deforms our 100 and 105-lb. rail heads, which are alike, as you will see in Figs. 29 and 30, pages 41 and 42, of the same report. The deformed rail head is worn away below its original contour on the gage side and the metal crowded over to the outside corner and builds it up square. To do this, metal must be displaced in the bearing surface, which tends to widen the gage. This is well illustrated on pages 41 and 42.

"The contours of the rail heads and also the wheel treads in position and their contacts on the rail heads are indicated just as they occurred. The areas of contact were taken on thin copper sheets under the locomotive and coal car wheels and are shown in Figs. 28 and 31. The locomotive had just come from the shop and the wheel treads were in good condition and smooth. (See Report No. 69, for rolling contacts and plotted measurements, pages 44 and 46.)

"The deformation of the rail heads to such contours shows that the majority of wheels concentrated their loads on the gage side instead of distributing them over a wide space of the bearing surface of the rail heads, which, as you know, is not the best practice. The concentrated wheel loads on the rail heads abrade the metal much faster than would be the case under a less intensity of pressure by the greater distribution of the wheel load to the metal of the rail head.

"The wheel treads with the chamfered outer portions, as shown in Fig. 33, page 45, wear the low rails on the curves hollow and crowd the flange of the opposite wheel against the rail head, causing severe flange abrasion, and quite as objectionable, increased train resistance. This type of contour on low new rails on the curves crowds the metal to the outside so severely that many split heads have occurred before the

metal in the bearing surface has been rolled, toughened and consolidated by the passing wheel loads.

"Inclining the rail head 1 in 20 with such wheel contours, the angle of the chamfer of the wheel tread runs against the top bearing surface of the low rail, forcing the flange of the opposite wheel on the axle against the inside of the outer rail head, as already described, and on long curves limits the car loads which the locomotives can draw. A number of complaints have been made to me the past few weeks about the increase in train resistance on curves, the locomotives often stalling with freight trains using the present M. C. B. contours on cast-iron wheels, which must be expected for the reasons already explained. It is probable that these features are not yet understood by operating railroad officials.

"The contours of the wheel tread should practically cover the rail head on the bearing surface and distribute the wheel loads vertically to the rail section. Then the rail head would wear over the entire width on top as occurred prior to the 1907 contours which the Chilled Iron Car Wheel Manufacturers' Association presented to the Master Car Builders' Association for their adoption, as recorded.

"You doubtless have noticed that the width of contact, both on rails on tangents and curves, at the present time is not more than three-eighths to one-half inch in width on the bearing surface, and is hardly increased by canting the rail 1 in 20. I have passed over many miles of track just after a rainstorm which had slightly dimmed the bearing surface of the rail heads and noticed that the wheels of a long passenger train did not brighten more than one-half inch in width of the metal on the rail heads."

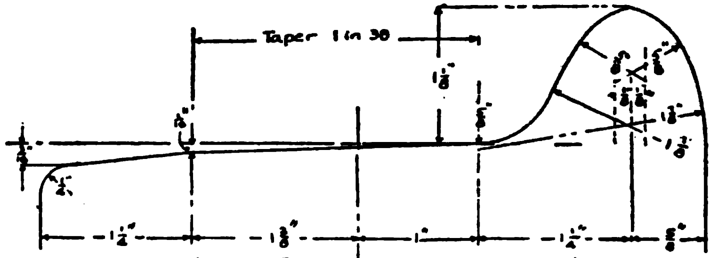
It would appear that the amount of taper for minimum wear of wheel is not the condition which results in economical wear and least stress in rail. In view of the fact that rail must be designed for the heaviest wheel loads, while the wheels are designed for a definite car capacity, it may be expedient to sacrifice some degree of service of wheel to favor the factor of safety and life of rail.

Attached is a statement of railroads reporting the use of canted tie plates or other methods of canting rail.

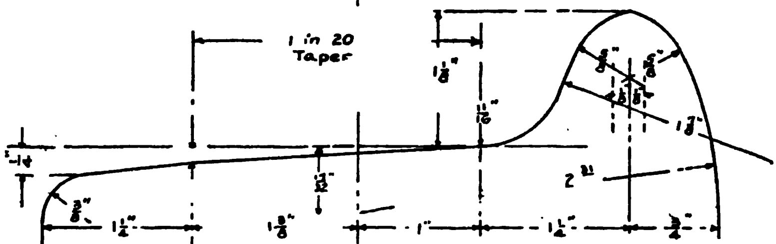
The Committee at this time has not received sufficient information as well as satisfied, to recommend whether or not the rail should be canted and to what extent. However, it does feel at this writing that the canting of rail 1 in 20, which is the same as the taper of tread of the Master Car Builders' standard, is too much. Therefore, from these general conditions which are cited, it would indicate that if the rail was installed and maintained in this position so as to provide a uniform bearing and wear on the head of the rail, which of course in turn would give you the best area of contact of the equipment, the best results would be obtained from wheel wear and rail wear. In recent years, the slightly extra length, or extra bearing, of the tie plate on the shoulder or outside of base of rail was the largest factor in this respect.

This report is in addition to the report the Committee made on the same subject and printed in the Proceedings of 1918, and the same is submitted as progress.

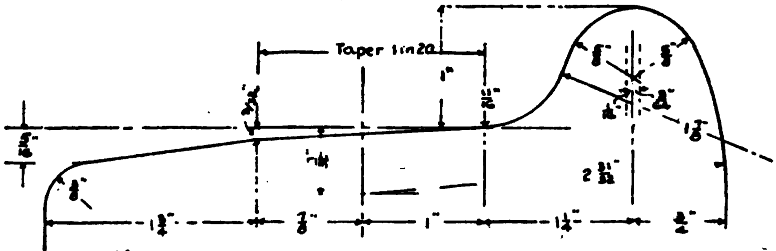
Wheel Contours.



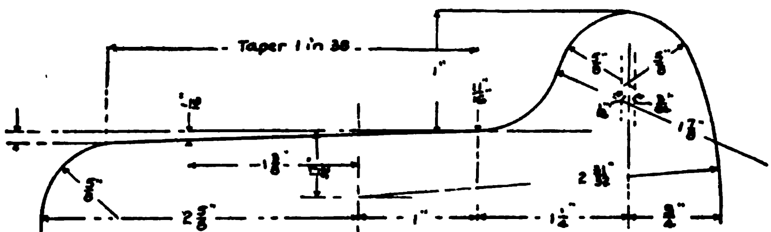
Adopted as Standard in 1886
M.C.B.



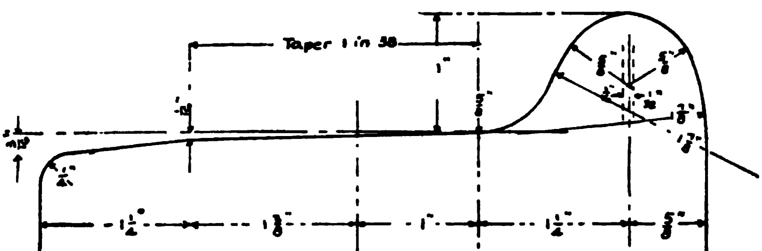
Adopted as Recommended Practice 1906 Advanced to Standard 1907.
M.C.B.



Modified Standard 1909. M.C.B.



N.Y.C.R.R. Standard Cast Iron Wheel - March 1916



N.Y.C.R.R. Standard Wheel Tread & Flange - Driving Wheel Tire
April 1912

TAPER OF TREAD OF WHEELS USED BY VARIOUS RAILROADS AND THEIR RECOMMENDATIONS AS TO CHANGING SAME.

Railroads Reporting	Miles of Track	Standard Wheel Taper for				Would greater or less taper		Would it be advisable to cant rail inward	How much	REMARKS
		Engine Drivers	Tenders	Passenger Cars	Freight Cars	Prolong life of Rail	Give greater wheel mileage			
Atlantic Coast Line	4700	1 in 20	1 in 20	1 in 20	1 in 20	No	No	No		
Boston & Albany	395	1 in 38	1 in 38	1 in 38	1 in 20			Yes	1 in 38	Taper of 1 in 38 used on steel tired wheels and Taper of 1 in 20 used on cast iron wheels.
Buffalo, Roch. & Pittsburgh	586	1 in 20	1 in 20	1 in 20	1 in 20	No	No	No		
Chicago & Alton	1033	1 in 20	1 in 20	1 in 20	1 in 20					No other data given.
Canadian Government	3803	1 in 20	1 in 20	1 in 20	1 in 20			Yes	1 in 40	
Canadian Pacific	13388	1 in 20	1 in 20	1 in 20	1 in 20	No	No	Yes	1 in 20	Recommend that 1 in 20 taper be retained.
Chicago & North Western	8000	1 in 20	1 in 20	1 in 20	1 in 20	No	No	Cant slightly in some places	No data	When worn steel wheels are turned down, coning is made 1 in 14½ for economy.
Central of New Jersey	684	1 in 20	1 in 20	1 in 20	1 in 20	No data	No data	No data		Doubtful whether any benefit would be derived by increasing or decreasing taper.
Chicago, Rock Island & Pac.	7657	1 in 20	1 in 20	1 in 20	1 in 20		No	No; on account of Frogs and Switches		Flatter taper would increase flange wear.
Del., Lack. & Western	981	1 in 20	1 in 20	1 in 20	1 in 20	No	Data given	No data given		Flatter taper would increase flange wear.
Denver & Rio Grande	2578	1 in 20	1 in 20	1 in 20	1 in 20	No	No	No		
Grand Trunk	4785	None	None	1 in 20	1 in 20	Yes, 1 in 40	Yes, 1 in 40	No		
Illinois Central	7185	1 in 20	1 in 20	1 in 20	1 in 20			No		
Michigan Central	1862	1 in 38	1 in 38	1 in 38	1 in 20					Taper of 1 in 38 used on all steel wheels.
Minneapolis & St. Louis	1646	1 in 20	1 in 20	1 in 20	1 in 20	No	No	Yes	⅛ inch	
New York Central (East)	3000	1 in 38	1 in 38	1 in 38	1 in 38	No	No	No		
New York Central (West)	2000	1 in 38	1 in 38	1 in 38	1 in 38	No	No	Yes	1 in 80	
N. Y., N. H. & H. R. R.	1992	1 in 20	1 in 20	1 in 20	1 in 20	No	No	Yes	1 in 60	Recommend that no change be made in taper.
Norfolk & Western	2085	1 in 20	1 in 20	1 in 20	1 in 20	No	No	Yes	No data	
Northern Pacific	7311	1 in 20	1 in 20	1 in 20	1 in 20	No	No	Yes	1 in 76	
Penna. (So. West. System)	4154	1 in 20	1 in 20	1 in 20	1 in 20	No	No	No		This taper is required to keep flanges from wearing.
Penna. (Lines East)	5412	1 in 20	1 in 20	1 in 20	1 in 20	No	No	No		No advantage to increase or decrease taper.
Philadelphia & Reading	1127	1 in 20	1 in 20	1 in 20	1 in 20					Believe that no change is necessary.
Pittsburgh & Lake Erie	224	1 in 20	1 in 20	1 in 20	1 in 20			Not canted		About to change standard taper to 1 in 38.
Seaboard Air Line	3461	1 in 20	1 in 20	1 in 20	1 in 20			No		Believe that no change should be made.
Southern	7922	1 in 20	1 in 20	1 in 20	1 in 20	No	No	No data		
Southern Pacific	7103	1 in 20	1 in 20	1 in 20	1 in 20			No		Not standard practice to cant rail inward.
Wabash	2519	1 in 20	1 in 20	1 in 20	1 in 20					No further data given.

Appendix C.

RAILROADS REPORTING USE OF CANTED TIE

Railroads Reporting	Miles of Rail-road	1 Have You Used Canted Tie Plates	2 Weight of Rail and Section on which Canted Tie Plates Are Used	3 Slope of Canted Tie Plate for Each Section of Rail	4 Size of Tie Plate Used with Each Section of Rail	5 No. of Plates for Each Section of Rail or Mileage	6 Length of Time Plates in Use	7 and 8 Rail Section Showing Effect of Wear
Atlantic Coast Line	4,700	No						
Baltimore & Ohio	4,548	Yes	90 lbs. A.R.A.-B	1 in 38	6"×8¼"	No record	10 years	None
Bangor & Aroostook	630	Yes	85 lbs. A.S.C.E. 70 lbs. P.S.	1 in 80	5½" 6"×8½"	24,700 11,300	6 years	None
Bingham & Garfield	35	Yes	65 lbs. A.S.C.E. 90 lbs. A.R.A.-A 90 lbs. A.R.A.-A	1 in 71 1 in 174 1 in 43½	8"×8" 8"×8½" 7"×10"	5,800 105,600	8 years 8 years 4 years	
Boston & Albany	395	Yes	105 lbs. Dudley.	1 in 44 1 in 40	6½"×9" 6½"×11"	336,000	3 years	None
Buffalo, Rochester & Pittsburgh	586	No						
Canadian Government	3,803	Yes	80 lbs. and 85 lbs	1 in 20 1 in 40	6½"×8½"	243,000	4 years	None
Canadian Pacific	13,388	Yes	56 lbs. and 60 lbs 65 lbs. 70 lbs. and 72 lbs 73 lbs. 80 lbs. 85 lbs. 100 lbs.	1 in 40 and 1 in 20 Present practice 1 in 20	6"×7⅞" 6½"×7⅞" 6½"×7⅞" 6½"×8½" 6½"×8½" 6½"×8½" 6½"×8½" 6½"×8½"	921,200 2,590,600 261,500 99,800 258,200 15,158,300 90,800	Installation started in 1911	No record
Canadian Northern	9,403	Yes	80 lbs.	1 in 40	6"×8½"			
Chicago & North Western	8,000	No						
Carolina, Clinchfield & Ohio	290	No						
Central of New Jersey	684	No						
Chicago, Burlington & Quincy	9,373	Yes	All weights	1 in 44	6"×8½"	Most of M.L. plates	8 years	
Chicago & Alton	1,033	Yes	70 lbs. 80 lbs. A.S.C.E. 90 lbs. A.R.A.-A	1 in 41½	6"×8½"		4 years	
Chicago Junction	219	No						
Chicago, Rock Island & Pacific	7,657	No						
Chicago & Western Indiana Belt R. R. of Chicago	52	Yes	75 lbs. 80 lbs. 100 lbs.	1 in 38 1 in 40 1 in 44	6"×8¼" 6"×8½" 6"×9"		8 years	

PLATES OR OTHER METHOD OF CANTING RAIL.

9 and 10 Instructions in applying. Ties Adzed. In or Out of Track	11 and 12 Use of Plates. Are Canted Plates being Generally Used?	13 and 14 Canting Rail without Use of Canted Plates. Amount of Slope.	15 Plates Placed with Rail Renewals or After Rail is Placed in Track	16 Cost	17 Any Saving by Placing Plates when Rail is Renewed	REMARKS
....	....	No	....	.....	.....	Do not recommend canting rails.
Applied same as flat plates. Ties adzed.	Plates used in renewals of soft wood and treated ties and on curves; also on all ties in renewals. Canted plates are not generally used........	No	With rail renewals	No data	Yes	Placing tie plates with rail renewals reduces cost, protects rail and ties and gets plates in service.
No special instructions	Plates used on all curves.	No	With rail renewals	No data	No data	....
Do not adze new ties...	Tie plates applied when rail or ties are renewed. Canted plates are generally used...........	Canted plates used on all tracks	With rail renewals	1½c with rail renewals 3c changing in track	Yes	Use of plate with 3" from shoulder to outside of plate and cant of 1 in 20 increases life of rail and ties. Experience shows 65 lb. rail, with plate having cant of 1 in 71 canted out ¼" on tangents and ½" on curves and ties, had to be adzed and rail rolled each year. The 90 lb. rail with plates canted 1 in 43½ have not had ties adzed after 4 years' service.
Both ways...........	Canted plates are generally used............	Not canted prior to use of tie plates	....	No data	Yes	....
....	....	No	....	.....	.....	Do not recommend use of canted plates.
Ties adzed in track....	Equip curves first regardless of renewing rail. Canted plates generally used.	No Ties adzed level	After	1.6c to 2.5c	.....	Rules for installing tie plates: No. 126—The std. form of tie plate will be used to prevent spreading of track, overturning of rails and the cutting of ties by the rails. Tie plates must be placed in pairs, one plate under rail on each end of same tie. No. 127—The end with the widest margin must be placed on the outside of rail. No. 128—When placing tie plates the tie should be carefully adzed the full length of plate, the spike holes plugged, the rail lifted, the plate slipped in and the track accurately spiked to gage.
No special instructions; only verbal ones.....	Yes; no flat plates have been bought since 1911.	Ties adzed. Amount of slope left to judgment of trackmen	Placed under all rail renewed; formerly after	.....	.....	
Not adzed..........	....	....	....	1½c	.....	Canted plates used on a good deal of new construction; placing them on curves of 3° and over.
....	....	No	....	.....	.....	Rail not canted unless done by trackmen in rolling and gaging rail.
....	....	By adzing ties 1 in 20	....	.....	.....	Roadmasters recommend use of canted plates.
....	....	No	....	.....	.....	Do not use canted plates or cant rail.
No special instructions Ties adzed in track....	Every new tie in main track to have tie plates. Canted plates generally used........	No	When rail is renewed	No data	Yes	Canted plates generally used, although flat plates are sometimes used under 90 lb. and 100 lb. rail.
Ties adzed in track.... Treated ties not adzed	Tie plate every tie in M. U. turnouts and alternate ties on curves 2° and over. Canted tie plate is standard...	....	....	.....	.....	....
....	....	No	....	.....	.....	....
....	....	No	....	.....	.....	Do not use canted plates, account of approaching frogs, switches and crossing frogs.
No instructions issued. Ties are adzed in or out of track to get flat bearing.........	Tie plates installed where needed, regardless of rail renewals. Canted plate is standard......	No	Before	No data	Yes	Recommend installing plates before rail is laid. Canted plates are used on all turnouts, on all M. U. passenger and freight tracks on curves over 1°, in yards on all ladder tracks and curved lead tracks; in fact, practically all C. W. & I. Main Side Yard or industrial tracks on curves are plated. In addition 5 miles of M. L. tangent of 100 lb. rail is plated with canted plates.

RAILROADS REPORTING USE OF CANTED TIE

(Continued.)

Railroads Reporting	Miles of Railroad	1 Have You Used Canted Tie Plates	2 Weight of Rail and Section on which Canted Tie Plates are Used	3 Slope of Canted Tie Plate for Each Section of Rail	4 Size of Tie Plate Used with Each Section of Rail	5 No. of Plates for Each Section of Rail or Mileage	6 Length of Time Plates in Use	7 and 8 Rail Section Showing Effect of Wear
Delaware & Hudson	909	Yes	80 lbs. A.S.C.E. 90 lbs. A.S.C.E.	1 in 80 1 in 86	6½"×8½"	360,000	3 years	....
Denver & Rio Grande	2,578	Yes	85 lbs. D.R.G.	1 in 40	6"×8½"	250,000	8 years	....
Erie	2,257	Yes	100 lbs. A.R.A-A	1 in 20	7"×10"	4,000	5 years	Sections furnished
Grand Trunk System	4,785	Yes	80 lbs. A.S.C.E.	1 in {20 40	6"×8½"	30,000	4 years	Sections furnished
Great Northern	8,198	Yes	100 lbs. A.S.C.E. 60 lbs. to 90 lbs.	1 in 46 1 in 80 for Secs. 75 to 90	6"×9¼" 6"×8" to 7"×9"	20,000 In use on practically entire line	11 years	....
Illinois Central	7,185	Yes	90 lbs. A.R.A.-A	1 in 20	7"×10¾"	5,500	3 years	....
Lake Superior & Ishpeming	160	Yes	....	1 in 83	....	....	....	....
Munising, Marquette & South Eastern.								
Lehigh & New England	294	Ordered	....	....	....	....	....	....
Long Island	397	Yes	100 lbs.	1 in 20	7"×10"	5,700	4 years	....
Maine Central	1,222	Yes	85 lbs. A.S.C.E.	1 in 96	5"×8"	30,000	2 to 8 yrs.	....
Michigan Central	1,862	Yes	100 lbs. A.S.C.E. 105 lbs. Dud....	1 in 20 1 in 20	7"×10¾" 7"×10"	2 Mi. 6 Mi.	3 years 2 years	....
Minneapolis & St. Louis	1,646	Yes	70 lbs. I. S. 7010 80 lbs. I. S. 8004 85 lbs. I. S. 8530 90 lbs. I. S. 9020	1 in 40	6"×8½" 6"×8½" 6"×8½" 6½"×9"	No data	2 years	....
Missouri Pacific	7,301	Yes	63 lbs. M. P..... 75 lbs. I. S. Co.. 85 lbs. I. S. Co.. 90 lbs. A.R.A-A.	1 in 76 1 in 83	6"×8" 6"×8½"	3,100 99,300 22,100 480,000	4 years	....
Mississippi River & Bonne Terre	64	Yes	75 lbs. A.S.C.E. 90 lbs. A.R.A...	1/16" under base of rail	6"×8" 6"×8½"	29,000	3 to 4 yrs.	....
New York Central (Lines East)	3,000	Yes	100 lbs. Dud....	1 in 44	7"×14"	4,000	6 years	....
N. Y. N. H. & H. R. R.	1,992	Yes	100 lbs.......... 107 lbs..........	1 in 60	6½"×10½"	1,135,000	4 years	....
New York, Ontario & Western	494	Yes	90 lbs. A.R.A.-B	1 in 20	7"×8½"	329,000	3 years	....
Norfolk & Western	2,085	Yes	100lbs. A.R.A.-B	1 in 20	7"×8½"	2,000	2 years	Rail sections furnished
Northern Pacific	7,311	Yes	66 lbs. N. P..... 72 lbs. N. P..... 85 lbs. A.S.C.E. 90 lbs. A.R.A.-B.	1 in 76 1 in 83 1 in 76	6"×8" {6"×8½" 7"×9" 7"×9"	200 Mi. 700 Mi. 1000 Mi. 1500 Mi.	9 years	....
Pennsylvania (Lines West)	4,154	Yes	100 lbs. P. S. Co.	1 in 20	7"×10"	12,000	2 years	....
Philadelphia & Reading	1,127	No	....	....	....	....	....	....
Pittsburgh & Lake Erie	224	No	....	....	....	....	....	....
Seaboard Air Line	3,461	No	....	....	....	....	....	....
Southern	7,922	No	....	....	....	....	....	....
Southern Pacific	7,103	No	....	....	....	....	....	....
Wabash	2,519	No	70 lbs. 80 lbs.	1 in 83 1 in 42	6"×8¼" 6"×8½"	....	....	....

PLATES OR OTHER METHOD OF CANTING RAIL.

9 and 10 Instructions in applying. Ties Adzed. In or Out of Track	11 and 12 Use of Plates. Are Canted Plates being Generally Used?	13 and 14 Canting Rail without Use of Canted Plates. Amount of Slope.	15 Plates Placed with Rail Renewals or After Rail is Placed in Track	16 Cost	17 Any Saving by Placing Plates when Rail is Renewed	REMARKS
No special instructions. Ties adzed level.......	Canted plates are generally used............	Yes; same as with plates	Both ways	No data	......	......
Ties adzed in track....	Not generally used......	No	With renewals	No data	......	Do not recommend canting rails.
Ties adzed in track....	Experimental..........	Yes; on curves	After	No data	No	......
No special instructions. Adzed in track when required............	Experimental..........	Not generally	With renewals	No data	Yes	Rules for use of tie plates attached to letter report.
No special instructions Ties not adzed.........	Confined to rail renewals. Canted plates generally used...........	......	......	......	......	......
Ties adzed in track....	Experimental..........	No	After	2c	Yes	......
......	......	......	......	......	......	......
......	......	......	......	......	......	16,000 Lundy plates ordered for 100 lb. rail.
Ties adzed in track....	Experimental..........	No	With renewals	No data	Yes	More canted plates ordered.
Ties adzed in track....	Used in renewals on curves. Canted plates not used last 6 years...	No	After	......	......	Canted plates applied 1909, 1910 and 1911 on curves. Taper of tread of wheels should be adapted to standard rail sections.
No special instructions Ties adzed in and out of track	Experimental..........	No	After	No data	Yes	......
Ties adzed in track....	Canted plates generally used................	Yes; same as with plate	Usually after	No data	......	......
Instructions to adze ties for full bearing..	Generally with rail renewals. Canted plates generally used........	No	With renewals	1.5c with 3.0c after rail renewals	Yes	Canted plates have been generally used, but on account of present steel market flat plates are used.
Adze ties to get full bearing............	Generally used with rail renewals............	Yes; when rail is to be rolled in by adzing	After	No data	No	......
Adze ties for full bearing................	Experimental..........	Adze ties for full bearing	After	5c	Yes	Screw spike tie plates; 2 lag screws and 2 screw spikes per plate. 15c adzing and boring; 5c applying plate.
Instructions attached to letter report. Ties adzed in and out of track.	Plates applied on curves on all treated ties. General use started....	Not done	After	No data	......	......
Level ties with adze. Generally in track...	Application confined to rail renewals.........	Ties adzed to cant rail	After	......	......	......
Applied on new ties. No adzing..........	Experimental..........	Ties adzed to give slope 1 in 20	After	2c	......	......
Instructions with letter report. Adze only for full bearing..	Used in renewals; also on every tie in rail renewals. Canted plates are generally used.......	......	With renewals	......	......	......
Method of applying in letter report. No special adzing done..	Experimental (on curves)	No	Both	2.84c	No data	......
......	......	No	......	......	......	Believe that they are a good appliance.........
......	......	No	......	......	......	......
......	......	Has been done on some curves.	......	......	......	Believe that they are a good appliance with slope 1 in 15.....
......	......	No	......	......	......	......
......	......	No	......	......	......	Occasionally rail is canted in by trackmen when rolling rail and regaging........
......	Canted plate is standard	......	......	......	......	......

Table Showing Miles of Track of Each Taper of Canted Tie Plates

Miles Single Track	With Taper of
18.8	1 in 20
3145.0	1 in 40
8.8	1 in 43½
0.6	1 in 44
190.0	1 in 60
1.0	1 in 71
2417.0	1 in 76
8239.0	1 in 80
1012.0	1 in 83
30.0	1 in 86
5.0	1 in 96
8.8	1 in 174
15076.0 Miles Total.	

Appendix D.

(6) CONSIDER THE ADVISABILITY OF REDUCING ALLOWABLE FLAT SPOTS ON FREIGHT CAR WHEELS—COLLECTING DATA AS TO DAMAGE DONE BY FLAT SPOTS.

This subject has been under investigation by various committees of the Association during the past ten years, but as yet no definite data has been obtained which convinced the Master Car Builders' Association of the necessity of a reduction in the allowable limit of flat spots. However, your Committee were, and are, unanimously of the opinion that a 2½-inch flat spot under a modern heavy freight car does create a severe damaging stress in the rail and that the present allowable limit of flat spots is excessive.

Forty years ago, in 1878, when the average freight car wheel load was but 8,250 lbs., the Master Car Builders' Association fixed the allowable limit of flat spots at 2½ inches, and although wheel loads have increased to 18,750 lbs. (100,000-lb. capacity car) and as high as 30,000 lbs., and the speed of trains is now much greater, the present Master Car Builders' rules retain the allowable limit at 2½ inches.

In 1916 your Committee endeavored to confer with the Master Car Builders' Association, but were informed that their executive committee were unanimously of the opinion that—

(a) Although maximum car capacity has greatly increased, there has been a corresponding increase in the strength and durability of cars and rails, so that relatively the 2½-inch limit remains quite safe.

(b) The corners of a 2½-inch flat spot soon become rounded so that the actual impact therefrom is much less than the theoretical; also the force of the blow is greatly diminished by the elasticity of car springs and roadbed.

(c) The reduction of the limit would mean tremendous expense for changing and scrapping flat wheels, and for these reasons the Master Car Builders' Association has steadfastly refused to consider suggestions from the American Railway Engineering Association that the allowable limit be reduced.

On the other hand, American Railway Engineering Association Committees, while admitting the lack of accurate corroborative evidence, have consistently contended for reduced limit, because—

(a) The impact from a flat-spot under the modern heavy car is many times greater than the impact from the car of 1878, when the present 2½-inch limit was fixed, due to much higher speeds and the fact that the maximum wheel load is now nearly four times heavier than in 1878.

(b) Actual tests have indicated that a 2½-inch flat spot delivers a serious blow to the rail.

(c) It is a fact that rails are broken by flat spots, though specific cases have been difficult to cite, because often the rail, while badly damaged, may not break until some time after the passage of the flat wheel.

(d) The reduction from 2½ inches to 1½ inches would not be very expensive, for the reason that very few additional car miles can be obtained before a 1½-inch flat has become 2½ inches, and, further, the greatest damage to the track occurs while the wheel is making these last few miles.

Your Committee, as the results of studies during the past two years, offers the following additional reasons why the allowable limit of flat spots should be reduced from 2½ inches to 1½ inches:

(a) Ordinarily, wheels having 2½-inch flat spots are removed from the axle and scrapped, whereas if the limit were fixed at 1½ inches, it would be possible to reclaim such wheels and replace them in service by grinding out flat spots without removing wheels from the axle and at a cost of about $0.60 per pair. Grinding is being done with excellent results on a number of roads and is recognized by authorities as good practice, provided, of course, that the wheel has not been burned during the process of flattening. Therefore, a reduction of the allowable limit from 2½ inches to 1½ inches would not only lessen the impact and damage to the rail, but should prove economical from the standpoint of service in life of wheels.

(b) While it is true that the strength and stiffness of rails has more than doubled (if we assume 60 lbs. and 100 lbs. A. S. C. E. section as the standards of 1878 and 1917 respectively) and as contended by the Master Car Builders' Association has almost kept pace with increasing wheel loads, it is a fact that this added stiffness of the rail and track structure actually augments the impact from a flat wheel, and this is especially true in winter. Recent tests on the Pennsylvania Railroad (A. R. E. A. Bulletin 200, page 162) show that the average load from a flat wheel recorded on frozen roadbed was from 15 to 25 per cent. greater than in warm weather tests.

Increasing the rigidity of the track structure reduces the distance in which a rail may deflect and absorb the energy of a blow from a flat wheel and consequently increases the impact.

There seems to be a misconception as to the meaning of the term "impact." For example:

A given blow from a hammer will not affect a nut placed on a soft rubber mat, but will crack a nut placed on an anvil, yet the striking blow is the same in both cases.

In other words, "impact" is something more than a "suddenly applied load" and must take into account the inertia of the resisting mass, deformation, etc.

Your Committee has reviewed various theoretical discussions and formulas to determine the impact caused by flat spots, but it is of the opinion that little practical benefit may be derived therefrom, because of the many uncertain and unknown quantities involved, such as shape of flat spot, condition of track, mechanical action of the wheel and car, etc.

Questionnaires were sent to fifty-five railroads for the purpose of securing data as to damage done to rails and opinions as to whether the present allowable limit should be reduced. Replies were received from twenty-six roads and may be summarized as follows:

Roads. *No.*	*Miles.*	*Favor Less Than 2½" Limit.*	*Remarks.*
16	51,393	Yes.	Three roads (5,395 miles) report several hundred rail failures due wholly to 2½" flat spots. The remainder favor reduction of limit, but have no specific data as to failures.
5	26,485	No.	Have no data to indicate that present limit should be changed.
2	3,705	No.	Regard present limit as O. K.
23	81,483		

CONCLUSION.

Your Committee is of the opinion that the allowable limit of flat spots should be reduced from 2½ inches to 1½ inches as a means of securing greater service life of both rail and wheels. We, therefore, respectfully suggest that the Association refer the above-mentioned facts to the Master Car Builders' Association, with the recommendation that the allowable limit of flat spots be fixed at 1½ inches.

REPORT OF COMMITTEE IX—ON SIGNS, FENCES AND CROSSINGS.

W. F. STROUSE, *Chairman;*
F. D. BATCHELDER,
H. E. BILLMAN,
C. G. BRYAN,
G. F. BLACK,
A. S. BUTTERWORTH,
B. J. DALTON,
F. T. DARROW,
G. N. EDMONDSON,
R. C. GOWDY,

ARTHUR CRUMPTON, *Vice-Chairman;*
PAUL HAMILTON,
MARO JOHNSON,
L. C. LAWTON,
S. L. McCLANAHAN,
L. A. MITCHELL,
T. E. RUST,
A. SWARTZ,
W. D. WARREN,
K. G. WILLIAMS,

Committee.

To the American Railway Engineering Association:

The Board of Direction assigned the following outline of work for the consideration of your Committee:

1. Make critical examination of the subject-matter in the Manual, and submit definite recommendations for changes.

2. Report on subject of "Signs," and the principles of design and rules for their use, considering the adoption of a sign for general use, as far as possible. Study in this connection, in collaboration with Committee on Signals and Interlocking, the design of suitable switches, stop posts, resume-speed posts, water station and trackpan markers, highway crossing signals, etc. Also consider the location of signs, having in mind the matter of safety of employees obliged to use the roadway.

4. Report on legal requirements relative to the provision of fences for right-of-way and stock yards.

5. Report on classification of fences into "types."

6. Make a comprehensive study of crossings:

(a) Grade crossings;
Crossing gates;
Crossing signal bells;
Warning signals.

(b) Over- and under-grade crossings;
Study the laws and requirements of the Federal Government and of the various states, provinces or municipalities which affect the distribution of cost as between the carrier and the public.

7. Make a careful investigation of all styles of manufactured posts that have been in use long enough to warrant conclusions as to their durability, with particular attention to:

(a) A study of various types of end or strain posts used with steel fence posts, with a view to recommending a type which would be a satisfactory substitute for posts set in concrete.

(b) An investigation as to the best method of bracing concrete end or strain posts.

Owing to conditions brought about by our entry into the world war, your Committee has this year been unable to devote the time heretofore

expended on the work, and in consequence has only made a study of items 6 and 7 of the above outline.

SUBJECT NO. 6-A—GRADE CROSSINGS.

A very marked improvement has been noted during the past two or three years in the matter of better protection of grade crossings. The great evolution in highway traffic which has taken place during the past fifteen or twenty years, in which the horse-drawn vehicle has been largely supplanted by the much faster motor vehicle, has greatly complicated the grade crossing problem. The greater speed of highway traffic to-day calls for a more comprehensive form of signal than was necessary under former conditions; for, as in train movements, there is need of definite early warnings. The motorist needs to be advised of the necessity of a stop in time to afford him ample opportunity to reduce his speed before reaching the point of danger. The old signs, calling upon the public to "stop, look and listen" before crossing tracks, are no longer adequate. In providing the necessary warning, the railroads have been confronted with a definite obstacle, since they must be installed at considerable distance from the track, and therefore usually outside the railroad property. They have therefore been without right to erect the signs or authority to maintain and protect them from injury.

The rational solution of this vexatious problem, therefore, seemed to be to place the responsibility for the cautionary signals on the state, county or municipal authorities, and this has been done in eight states, as shown by the report of the National Association of Railroad and Utility Commissioners, presented at its convention in Washington, October 16, 1917. There should be no controversy as to the justice of this decision, as the matter of safety on public highways should be as carefully guarded by their properly constituted authorities as that provided by the railroads.

The pioneer state in this movement was New Hampshire, which was later followed by Vermont, Massachusetts, Connecticut, Maine, California, Oklahoma and Illinois. Bills providing for similar laws have been presented to the legislatures of a number of other states, upon which action is still pending.

Most of the laws that have so far been passed contemplate locating these signs about 300 feet from the tracks, when, in the judgment of the commission, the crossing involves such hazard as to require the installation of a "stop" sign at the crossing; and, with the exception of those of Connecticut, imposes the erection and maintenance of warning signs outside of the railroad right-of-way on the highway commissioners who have authority over the ground upon which the signs are installed, while the installation and maintenance of "stop" signs in close proximity to the tracks and therefore usually inside the right-of-way is imposed on the railroad.

The report shows that the design of signs used in New Hampshire and Vermont is not similar to that later adopted by the Association. In Connecticut the cautionary signs must be furnished by the railroads, but installed by the State, County or City authorities. In California the law requires vehicles approaching grade crossings of railroads to run at a speed not exceeding fifteen miles per hour. Tennessee has a law requiring automobilists to come to a stop before crossing railroad tracks. Texas laws require them to reduce speed to six miles per hour at all crossings except those protected by gates or flagmen. The state of Washington has a law requiring automobiles carrying passengers to stop before crossing railroad tracks.

The order of the Public Utilities Commission of Illinois, issued July 31, 1918, in the execution of statutes passed by the state legislature in June, 1917, prohibits the installation of any other signs or signals, such as advertising notices, within 300 feet of any railroad grade crossing, to prevent any possibility of confusion with the regular crossing protection signs. This is an excellent provision, but does not go far enough. Rigid restrictions should be placed on the erection of unnecessary signs anywhere on the public highways. The motorist's attention is too often jaded by signs containing misleading inscriptions, and until such notices and signs of fantastic design are prohibited, there will, of necessity, be more or less confusion with actual warning signs.

The Commission's order included explicit specifications and drawings for both the "stop" and "approach" signs. They must be made of No. 16 gage porcelain-enameled metal, crimped backward at least ½ inch around the perimeter. The letters must be black on a white field and the rear of the sign is painted black. The supporting post may be either wood or iron, but must be of sufficient strength to make a solid and substantial support. The posts must be designed to permit a bracket or attachment to be installed for the purpose of supporting a light or signal at night, wherever, in the opinion of the Commission, this may be necessary.

The painting of black and white diagonal stripes on crossing gates and the use of circular disks instead of flags by crossing watchmen have now become common on many railroads.

The above-mentioned report not only deals with better protection of grade crossings, but gives a comprehensive review of the entire crossing question, including joint action with the American Railway Association, which resulted in the adoption of some important standards.

In the matter of number of grade crossings, it summarizes figures that show the enromous magnitude of the problem. Over 110,000 grade crossings were reported in the twenty-two states from which replies to a circular letter were received. Basing calculations on the above data, it is estimated there are about 200,000 grade crossings in the United States and that there are about 2,000 persons killed annually at these crossings. It further appears from the reports that in the above twenty-

two states only about ten per cent. of the crossings are protected by gates, flagmen or bells.

Of the 826 grade crossings on the Maine Central Railroad, in the state of Maine, 97 are provided with gates, 62 are protected by flagmen, 13 by automatic signals, while the remaining 654 are unprotected, indicating that between 20 and 21 per cent. are protected, which appears far above the general average. To further provide against accident on the above road, the Public Utilities Commission had all the crossings investigated and made an order directing the company to clear the view at a great many crossings by cutting bushes, trimming trees and in some cases removing knolls and other obstructions which prevented a clear view of approaching trains for travelers on the highways. It also ordered the installation of 55 additional automatic signals.

It is understood that an attempt will be made to change the law so that the automatic flagman will not give an audible signal. It is thought this proposition will be seriously opposed by residents of the more thickly settled districts.

In the matter of grade crossing elimination, considerable progress has been made in Connecticut, Illinois, Massachusetts, New Jersey, New York, Oklahoma, Oregon, South Carolina and Wisconsin. Massachusetts, with only about 2,000 miles of railroad, has spent in the past thirty years about $42,000,000; Illinois, in a much shorter period, has done work involving an expenditure of over $55,000,000, much of it in the city of Chicago; New York, with about 8,000 miles of railroad, has spent about $44,000,000. Estimates of cost of elimination of grade crossings have been prepared in a few states running into hundreds of millions of dollars. In California the average cost is estimated at $30,000 each; in Colorado at $40,000; in New York at $48,000, and in Wisconsin at $25,000.

Placing the average cost of eliminating grade crossings at $40,000 and assuming the number at 200,000, it would cost the railroads and the public $8,000,000,000, a burden the railroads and the public could not bear unless distributed over a long period of years. With a clear vision of the utter impossibility of financing such a gigantic scheme, the state, county and municipal officers are giving the railroad officials more effective cooperation in obtaining a better protection of grade crossings. Our entrance into the world war developed a well-defined policy against expenditures for railway improvements which did not directly benefit the handling of traffic. All efforts, therefore, should be directed toward improving rather than eliminating grade crossings, and the standardization of signs would be a step in the right direction.

Considerable information has already been presented to this Association bearing on the division of cost as between the railroads and the public. Notwithstanding conditions brought about by the war, it is the opinion of the Committee that some progress should be made each year toward the elimination of grade crossings, particularly those where the hazard and delay is greatest and the cost of maintaining watchmen is

heaviest. It further occurs to your Committee that the most equitable plan for the division of cost is that of New York, where the burden is imposed equally on the railroads and the public.

CROSSING SIGNAL BELLS.

In the matter of crossing signal bells, your Committee wishes to present the following information relative to the performance of six Hoeschen crossing bells installed by the Waterloo, Cedar Falls and Northern Railway Company in January, 1915.

This type of bell is mechanically operated, the depression of the rail at different points serving to wind the clockwork of the bell and generate the electrical impulse which trips the clockwork and starts the bell ringing. One of these bells was installed on a line that has been in service about twenty years. The other five bells were installed on the Cedar Rapids district, which had only been in operation about four months when the installation was made.

At the time the installation was made the Hoeschen Company was just beginning the use of what was thought to be an improved mechanism for generating the momentary current necessary to ring the bell. This instrument soon proved a failure and was replaced after some six or seven months' trial. In the meantime, out of 34,888 train movements, there had been 1,162 failures, or about 3.33 per cent., and one fatal automobile accident, which very probably would have been avoided had the bell not been out of commission at the time. On account of the numerous failures during this period, the performance records prior to August 1, 1915, were of little value. Between that time and October, 1916, a careful record of the performance of these bells was kept, as well as the cost of labor and material used in inspection and repair, as shown by the following tables:

TABLE I—FAILURES AND MAINTENANCE COST.

	A	B	C	D	E	F
		Total Failures.				
Month.	Total Train Movements.	Number Cases.	Train Movement.	Percentage of Failures.	Total Cost Inspection and Maintenance.	Average Cost of Maintenance and Inspection per Month.
August, 1915	5,642	3	23	0.41	$ 3.00	$0.50
September	5,360	4	27	0.50	4.76	0.79
October	5,542	3	32	0.58	3.75	0.62
November	5,460	1	1	0.02	10.00	1.67
December	5,642	5	87	1.54	8.50	1.42
January, 1916	5,642	9	118	1.95	19.60	3.27
February	5,278	2	65	1.23	10.00	1.67
March	5,642	6	52	0.92	5.00	0.83
April	5,330	6	23	0.43	5.75	0.96
May	5,498	3	3	0.05	6.00	1.00
June	5,330	0	0	0.00	0.00	0.00
July	5,488	7	54	0.98	27.25	4.54
August	5,498	0	0	0.00	10.50	1.75
September	5,340	1	1	0.02	1.75	0.29
October	5,642	1	21	0.37	4.75	0.79
Total	82,344	51	497		$120.60	
Average per month	5,489	3.4	33	0.60%	8.04	
Average per bell per month	915	0.6	6		1.34	

TABLE II—ANALYSIS OF CAUSES AND FAILURES.

	Track Conditions.		Bell Mechanism.				
Month.	Soft Track.	Soft Ties.	Adjustment.	Failure Mechanism.	Defective Wiring.	Unknown and Miscellaneous.	Total.
August, 1915	..	1	2	..	..	..	3
September	2	1	1	..	..	..	4
October	2	..	..	1	..	..	3
November	..	..	1	..	..	..	1
December	..	..	..	..	4	1	5
January, 1916	..	3	..	1	2	3	9
February	..	..	..	1	1	..	2
March	..	..	1	4	..	1	6
April	2	..	1	1	..	2	6
May	..	..	..	1	..	2	3
June	..	..	..	..	..	..	0
July	..	2	..	1	..	4	7
August	..	..	..	..	..	..	0
September	..	..	..	1	..	..	1
October	..	..	..	1	..	..	1
Total	6	7	6	12	7	13	51
Per cent.	12	13	12	25	13	25	..

TABLE III—PERFORMANCE OF INDIVIDUAL BELLS.

Month.	Whitney Road. No. Failures.	Whitney Road. % Failures.	Evans. No. Failures.	Evans. % Failures.	Cheney, West. No. Failures.	Cheney, West. % Failures.	Cheney, East. No. Failures.	Cheney, East. % Failures.	Wallace. No. Failures.	Wallace. % Failures.	Quass. No. Failures.	Quass. % Failures.
August, 1915	0	0	2	1.9	1	1	0	0	0	0	0	0
September	0	0	2	0.8	0	0	0	0	2	2.8	0	0
October	0	0	1	1.3	0	0	0	0	2	2.8	0	0
November	0	0	0	0	0	0	0	0	1	0.1	0	0
December	0	0	0	0	1	1.9	1	1.9	3	6.8	0	0
January, 1916....	0	0	3	4.6	2	2.0	2	2.0	1	0.1	1	4.5
February	0	0	0	0	0	0	0	0	2	8.6	0	0
March	0	0	0	0	2	3.0	2	3.0	2	0.5	0	0
April	0	0	1	0.1	1	0.7	3	2.1	1	0.1	0	0
May	0	0	2	0.3	0	0	0	0	1	0.1	0	0
June	0	0	0	0	0	0	0	0	0	0	0	0
July	0	0	6	3.8	1	3.1	0	0	0	0	0	0
August	0	0	0	0	0	0	0	0	0	0	0	0
September	0	0	0	0	0	0	0	0	0	0	1	0.1
October	0	0	1	2.7	0	0	0	0	0	0	0	0
Total	0	0	18	15.5	8	11.7	8	9.0	15	21.9	2	4.6
Ave. per month..	0	0	1.2	1.03	0.5	0.78	0.5	0.6	1.0	1.46	0.1	0.03

Table I shows the performance of the six bells referred to above. Column "A" shows the number of train movements per month or the total number of alarms that would have been sounded had every bell operated each time a train approached it. Column "B" shows the total number of bell failures during the month. Column "C" shows the total number of train movements during period the bells were not operating. Column "D" shows the percentage of train movements made during the period the bells were not operating or when no protection was afforded. Columns "E" and "F" show total cost of inspection and maintenance per month and average cost of inspection and maintenance per month per bell. It will be noted, therefore, that column "B" indicates the actual performance of the bells, whereas columns "C" and "D" are largely affected by the promptness with which repairs are made or trouble corrected.

From the table it will be noted there is an average of about ten unprotected train movements each time a bell fails to operate. This rather poor showing in the matter of maintenance is due to the maintainer being employed on other work most of the time and therefore not immediately available. Attention is further called to the fact that most of the failures reported are due to trouble with the generator rather than with the mechanism of the bell, and that a generator failure causes the bell to fail for train movements in one direction only, the crossing still being protected from trains approaching in the other direction. With bells operated by track circuits, a failure usually means that no alarm is

sounded for train movements in either direction. This fact should be borne in mind when making comparisons of the number of failures of this type of bell with those of the track circuit type.

Table II shows the *causes* of failure, from which it will be noted that an average of about 25 per cent. are due to failures of the bells or generator mechanism, 25 per cent. to miscellaneous or unknown causes, and that the balance are about evenly divided between soft track, cutting of rails into soft ties, incorrect adjustment of apparatus and defects or short circuits in the wiring. A large number of the failures assigned to unknown or miscellaneous causes are due to the reported failures of bells, which were found by the maintainer to be working perfectly when examined, making it doubtful if any failures actually occurred, and the balance to an experimental oiling device installed by the maintainer on his own initiative.

Table III shows the performance of each bell. The first one, Whitney Road, did not have a single failure between June, 1915, and October, 1916. This is the bell noted above as having been installed on the line built about twenty years ago, and its remarkable performance suggests that while many of the failures at other points have been charged to various causes, the fundamental cause of nearly all the trouble could probably be charged to unstable track conditions due to recent construction of that portion of the road. Another condition contributing to the difference in operation is that heavy freight trains of twenty or twenty-five cars are hauled daily over this portion of the road, whereas only short freights and comparatively light interurban cars are operated over the line on which Whitney Road bell is located.

The more severe service affects bell operation in two ways. The heavy freights have a tendency to injure the surface of the track and the mixing of long freight and one or two passenger car trains makes it more difficult to adjust the winding mechanism of the clockwork of the bell, which is likely to be wound so tightly as to stop the operation, or not enough to cause the bell to continue to ring during the entire time trains are running some 2,000 feet from the track generator to the bell. No satisfactory explanation can be offered for the relatively poor average showing of the Evans bell. Track conditions are good and it should show the best performance. At Cheney there are two bells, about 800 feet apart, operated by the same set of generators. The poor showing of the Wallace bell is easily understood, as it is located in a deep cut where track and drainage conditions are not very good. The Quass bell is on a curve with the rails supported on heavy tie plates, which explains in some degree the good results obtained. Tie plates have since been installed at the other locations.

Since the entry of the United States in the war and the consequent shortage of help, the keeping of records showing the performance of these bells has been discontinued. However, the efficiency and maintenance of these bells since have been about the same as indicated in the above reports.

Sample Report.

HIGHWAY CROSSING BELL.

Failure Report.

TIME.

Location.	Failure Reported.	Repaired and Operating.	Number of Train Movement Failures. EAST.	WEST.
Wallace	9-2-16 8:40 A. M.	9-2-16 4:30 P. M.	10	0

Cause of Failure: Rail cutting into soft ties at east generator.
COST:
TIME in Labor: 8 hours section laborers, 10 hours maintainer.
Supplies Used: None.
REMARKS: Tie plates or hardwood ties needed.
Date: 9-3-16.

Harry Evarts, Bell Maintainer.

SUBJECT NO. 7—INVESTIGATE TYPES OF MANUFACTURED POSTS.

Early in September last the following circular letter was addressed to the officials of about thirty railroads soliciting information on concrete and steel posts:

"Your Company has in the past few years furnished information relative to the use of concrete and steel fence posts. It is desired this year to report on progress in this field, and the following brief list of questions is submitted for your consideration. It is intended that your replies shall relate particularly to the developments of the past year, but any information which you have not previously reported will be gratefully received:

(1) To what extent have you used concrete or steel posts during 1918?

(2) Kind or type of post used.

(3) Have you used any type of steel strain post without setting in concrete? Describe briefly and comment on its effectiveness and economy.

(4) Have you used braces other than wood for concrete strain posts? Describe briefly and comment on the effectiveness and economy of the device.

(5) Report any other matter of interest relating to fence posts of any type."

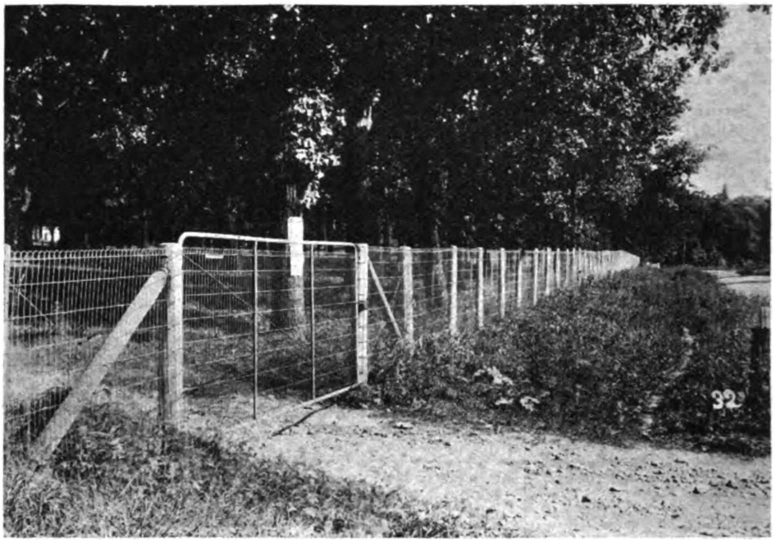
The data received in reply to the above letter of inquiry will be found in the accompanying table. Only nineteen replies were received—fourteen of which were to the effect that no concrete posts were used during the year and ten to the effect that no steel posts had been used. From the remaining replies it will be noted that only two companies used concrete posts to any extent and that only one company used steel posts in quantity. This was, no doubt, due to the high price of steel in the case of steel posts, and to the high price of labor and material entering into the manufacture of concrete posts. This condition is likely to continue until normal prices are restored.

DATA ON CONCRETE AND STEEL FENCE

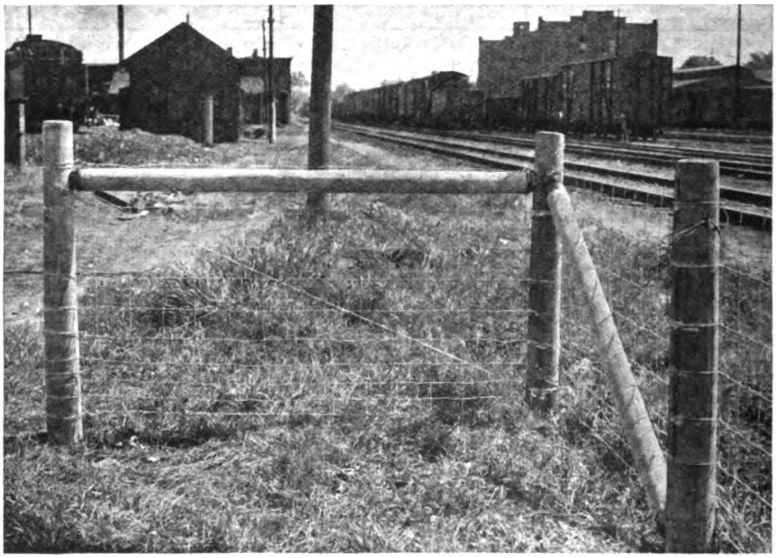
Railroads	To What Extent Have You Used Concrete or Other Fence Posts during 1918?		Kind or Type of Post Used	
	Concrete	Steel	Concrete	Steel
Atlantic Coast Line	None	None	....	....
Baltimore & Ohio	None	None	....	....
Boston & Albany	None	1917	....	1,000 Chicago angle, 917 Am. S. & W. Co....
Chicago, Rock Island & Pacific	None	None	....	....
Cleveland, Cincinnati Chicago, & St. Louis	About 35,000 line. About 2,000 end...	....	Nat. Conc. Mach. Co..	....
Duluth & Iron Range	None during 1918.......	124-10' line posts. 8 corner posts..	....	Am. S. & W. Co........
Elgin, Joliet & Eastern	None	300	....	Am. S. & W. Co. 7' line, 8' end.....
Gulf & Ship Island	None	270	....	Conners-Wymore Co. angle line........
Illinois Central	About 30,000	None	Nat. Conc. Mach. Co. 7' long-1-2-4	....
Long Island	Concrete posts used exclusively	....	4' and 5' reinforced...	....
Louisville & Nashville	Very few used since 1916.......	....	D. & A....	....
Mississippi River & Bonne Terre	None	None	....	....
Missouri Pacific	None	None	....	....
Northern Pacific	None	None	....	....
Pennsylvania Lines (West)	None	Not extensively during 1918....	....	7' to 7½' long No. 16 Am. S. & W. Co.
Peoria & Pekin Union	None	None	....	....
Toledo & Ohio Central	None	None	....	....
Wabash	None	A few old boiler tubes	....	....
Waterloo, Cedar Falls & Northern	None	None	....	....

POSTS, STRAIN POSTS AND BRACES, 1918.

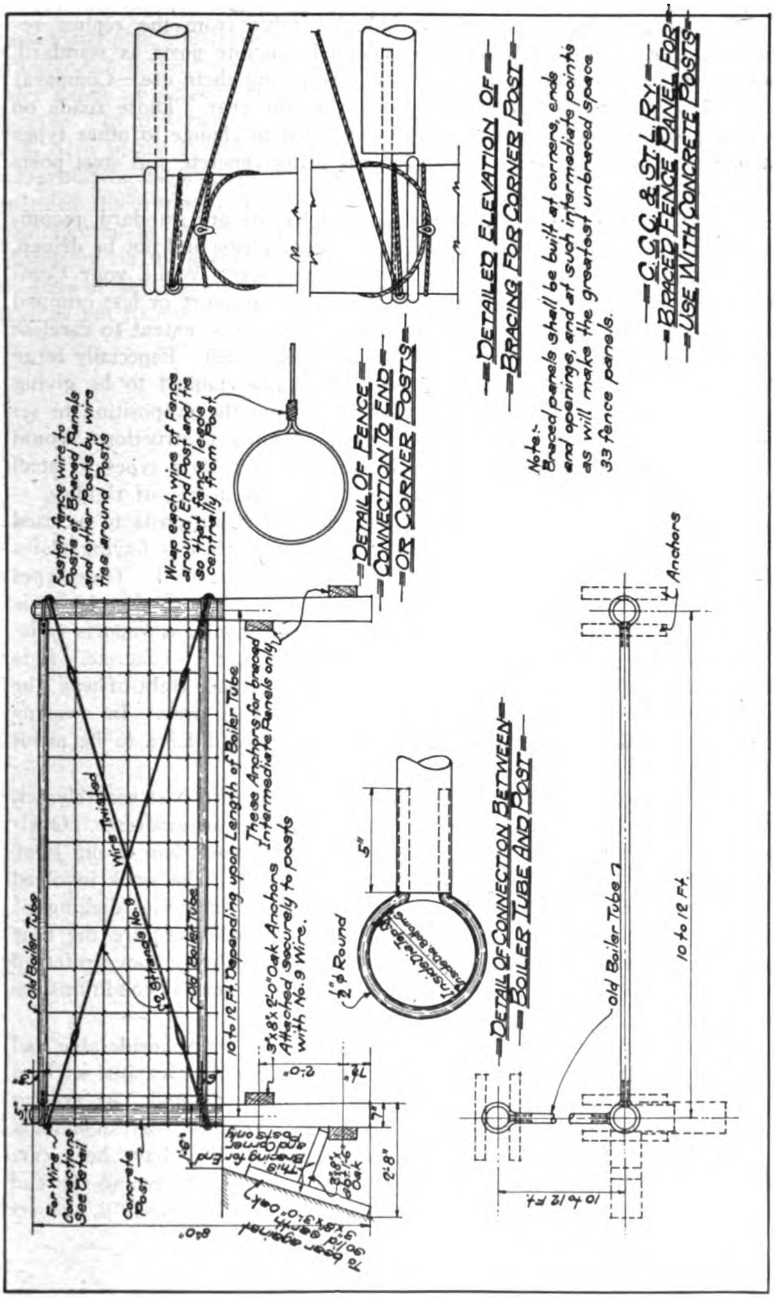
Have You Used Any Type of Steel Strain Post without Setting in Concrete? Describe Briefly, Etc.	Have You Used Braces Other Than Wood for Concrete Strain Posts? Describe Briefly and Comment on, Etc.	Report Any Other Matter of Interest Relating to Fence Posts of Any Type
No	....	....
....	....	Will not use steel or concrete until they can be furnished more cheaply.
No strain posts on Chicago, Am. S. & W. Co. set in concrete....................	Have used no concrete strain posts....................	Find steel fence posts quite satisfactory.
....	....	....
No	Braces made from old boiler tubes found satisfactory....	Concrete posts cheaper and more satisfactory than cedar.
End posts set in concrete.....	2-inch iron pipe brace anchored in concrete.........	These posts were used in protective fence about shop grounds.
All strain posts set in concrete	No concrete strain posts used in 1918....................	Am. S. & W. Co. posts are being used as standard.
No	No	Nothing of interest to report.
No	No	Complete plants manufactured by National Concrete Machinery Co.
No	Use wood braces only........	Nothing to report.
No	No	....
Steel strain posts are all set in concrete..................	Old boiler tubes for the past 8 years. Satisfactory......	Sides of posts have recesses to receive braces.
....	....	Nothing to add to reports made in October and November, 1917.
....	....	....
Reliable steel post with steel brace made by Am. S. & W. Co....................	Concrete braces with wood, concrete and steel posts....	Steel fence posts used extensively prior to 1918. Service satisfactory.
Am. S. & W. Co. thoroughly tamped with earth.........	1½-inch steel braces with plate bedded in ground....	....
No	No	....
....	....	....
....	....	....



National Gate, Brace and Line Posts Around Monona Park, Madison, Wis.



National Corner Posts and Brace Posts.


C. C. C. & St. L. Ry.
Braced Fence Panel For
Use With Concrete Posts
Detailed Elevation of
Bracing for Corner Post
Note:- Braced panels shall be built at corners, ends and openings, and at such intermediate points as will make the greatest unbraced space 33 fence panels.
Detail of Fence
Connection to End
or Corner Posts
Detail of Connection Between
Boiler Tube and Post
Fasten fence wire to Posts of Braced Panels and other Posts by wire ties around Posts
Wrap each wire of Fence around End Post and tie so that fence leads centrally from Post
These Anchors for braced Intermediate Panels only
10 to 12 Ft. Depending upon Length of Boiler Tube
3"x8"x2'-0" Oak Anchors Attached securely to posts with No. 9 Wire.
1/2" ϕ Round
Old Boiler Tube
Wire Twisted
12 Strands No. 9
For Wire Connections See Detail
Concrete Post
This Bracing for End and Corner Posts only
To bear against solid earth
3"x8"x3'-0" Oak
3"x8"x2'-6" Oak
Anchors
10 to 12 Ft.
8'-0"
2'-8"
2'-0"
5"

So far as your Committee is able to judge from the replies received, those companies which have adopted concrete posts as standard, and have been large users of them, are continuing their use. Comparatively few steel posts have been used during the year. Those roads on which wood posts are standard are not inclined to change to other types at present prices. In general, those roads using concrete and steel posts report satisfactory service.

One Chief Engineer, on whose road steel posts are standard, recommends that all steel posts should be set as other posts, and not be driven, in order to avoid damage to the tops of the posts. While your Committee is aware that the tops of some steel posts are more or less crimped or battered in driving, it is believed to be due to some extent to careless driving, and to the use of a cap not properly designed. Especially large driving caps are now being furnished, which are claimed to be giving satisfaction. Your Committee therefore feels that the proposition to set all steel posts, except in the case of rock or other obstructions, would defeat the whole plan of economy in the use of certain types of steel posts, besides the difficulty of setting them with any degree of rigidity.

(a) Information in regard to steel end and strain posts to be used without concrete bases was submitted last year, and braces having plates attached, which are driven in the ground, were described. (See types A and B, page 656, last year's report.) Satisfactory use of this device is reported by one company this year, while another company reports satisfactory service from strain posts set without the use of concrete. It is estimated that along about 90 per cent. of railroad right-of-way the driven end posts would prove satisfactory in every way. In swampy ground or rock the preparation for anchorage would have to be about the same as for wood posts.

The main point under consideration is to have the post securely set, and of next importance to have the cost of installation moderate. Obviously, it takes much less time to drive a steel end post than to dig large holes and fill them up again with concrete or earth. The work involved in setting an end post with the necessary bracing, including digging of holes, refilling with concrete or earth, would probably require the time of two men about two hours—while the end post and brace above referred to and described in last year's report could, under normal conditions, be set in about fifteen minutes.

In normal times the saving in labor would be very considerable and so far as efficiency is concerned, the driven post would give just as long and satisfactory service as a post set by any other method. At present prices of labor and material, the advantages would be correspondingly great. So far as the investigations of your Committee have been carried, it is of the opinion that the method of setting and bracing the end post illustrated on page 656 of last year's report, marked type "B," represents the best scheme thus far brought to its attention.

(b) In the matter of bracing concrete end or strain posts, the accompanying plan, illustrating the use of old boiler tubes, is presented. This arrangement is said to be very satisfactory. The satisfactory use of boiler tubes as braces, covering a period of about eight years, is also reported. In this case the braces were simply set in holes cut about ¾-in. deep in the sides of the posts, the ends of the tubes being cut to correspond to the angle at which the braces were set. Photographs are appended illustrating a 4-inch diameter concrete brace made in molds, manufactured by the National Concrete Machinery Company. Cast-iron sockets are set in the posts, into which the rounded end of a casting on the ends of the braces are fitted. This device is used by a good many farmers, but its use so far by the railroads is rather limited.

Respectfully submitted,

COMMITTEE ON SIGNS, FENCES AND CROSSINGS.

REPORT OF COMMITTEE XIX—ON CONSERVATION OF NATURAL RESOURCES.

R. C. YOUNG, *Chairman;*
R. H. AISHTON,
W. K. BARNARD,
C. B. BROWN,
MOSES BURPEE,
MAJOR C. H. FISK,
E. E. KING,

S. N. WILLIAMS, *Vice-Chairman;*
WILLIAM MCNAB,
W. F. OGLE,
J. L. PICKLES,
J. W. VOTEY,
W. C. WILLARD,

Committee.

To the American Railway Engineering Association:

Your Committee on Conservation of Natural Resources was instructed to consider the following subjects by the Board of Direction:

1. Continue the study of tree planting and general reforestation.
2. Report on the conservation and utilization of water power for railway purposes, conferring with Committee on Electricity.
3. Report on the study of coal, fuel-oil, timber, iron and steel resources.
4. Report on the relation of railways to the different conservation projects, reviewing work that has been done by each company up to the present time, and make recommendations on policies economical for railways to follow.
5. Report on measures for the conservation of human life and energy.

The Committee held two meetings, both at Chicago—the first on July 10, and the second on December 18.

After careful consideration, the Committee decided to confine its efforts to the subject of "Conservation of fuel," and submits herewith the result of its deliberations in two appendices—one relating to the conservation of fuel in the United States, and the other on the developments in Canada.

Your Committee submits the report as information and recommends that it be received as such.

Respectfully submitted,

COMMITTEE ON CONSERVATION OF NATURAL RESOURCES.

Appendix A.

STUDY OF THE CONSERVATION OF FUEL.

Just at the very moment when our country was engaged in the supreme effort of its lifetime to "make the world safe for democracy," when it was speeding up its war industries to the limit and straining every nerve to deliver a maximum of men and equipment to the battle line, there came a shortage of coal. While the signing of the armistice will relieve to a certain extent the demands abroad, the requirements at home will be as persistent as ever, for there must come a period of reconstruction. During this period the leading industries will simply change their product from a war to a rehabilitation basis and continue as active as they were before the armistice was signed. Those industries not necessary to the winning of the war that were obliged to curtail their production to economize on fuel will now seek to recuperate their interests by a speed-up program of production. On account of the shortage of coal brought on by the exigencies of war and which, no doubt, will continue on account of the reconstruction needs, the Committee feels that it should confine all of its attention this year to a study of the conservation of fuel.

Of the total amount of coal used in the United States in 1917, 544,000,000 tons were bituminous and 77,000,000 were anthracite. As the railroads consumed 175,000,000 tons of this, or nearly one-third of the total output, their fuel question becomes one of huge proportions and demands the most serious thought and attention that they are able to give it.

Figures furnished by the United States Railroad Administration show that during 1915 the railroads of the country used 122,000,000 tons of bituminous coal at an average cost of $1.13 at the mine and during 1917, 155,000,000 tons at an average cost of $2.13 at the mine. They estimate that during 1918 the railroads will use 166,000,000 tons of bituminous coal at an average cost of $2.50 at the mine. Although there were 544,000,000 tons of bituminous coal mined last year, which is 41,000,000 tons more than had been mined in any previous year, there was still a shortage of 60,000,000 tons and it is estimated that it will be even more this year.

There are three ways of relieving the situation:

1. By getting a better grade of coal from the mines.
2. By increasing our facilities for transportation.
3. By practicing conservation.

If the mines will see that better and cleaner coal is delivered to the railroads it will save them transporting thousands of tons of slate, rock, and other impurities commonly found in bituminous coal. These surplus materials are an additional burden, not only to the railroads that haul them, but also to the consumers that use them, for they decrease the efficiency of the power-plant and increase the size of the ashpile.

The Railroad Administration is ordering new equipment and is repairing that which it already has; but even then it cannot cope with the situation, for the roads must handle a heavier tonnage than they have ever handled before. They must haul raw material to the industries, they must carry foodstuffs and provisions for the Army and Navy, and they must move soldiers from the camps and the water-front.

The greatest possibility seems to lie in conservation. Statistics show that during 1917 the total equipment for handling coal constituted about one-third of all the traffic of the country. The transportation of fuel becomes then a problem of extraordinary magnitude and offers enormous opportunities for saving by the railroads and other industries of the country. As the railroads use nearly one-third of the total amount of coal consumed, a heavy responsibility rests with them in meeting the nation's need. If by some intensive effort to conserve the supply of coal, such as is outlined in the following pages of this report, the railroads alone can save 6,000,000 tons of coal a year they will relieve themselves of handling 100,000 carloads of non-revenue tonnage. As they are experiencing a shortage of cars to handle the great volume of freight, this saving in coal not only will eliminate a dead loss in hauling the coal itself, but will relieve those cars for such public service as is demanding transportation. To make such a saving effective every person in the railroad service should be impressed with the importance of conserving fuel and should be instructed concerning the best methods of procedure.

One-fifth of all coal burned in locomotives is used when the engines are not moving trains. Some of this is consumed at engine terminals and some on passing tracks waiting for trains to meet. Most of this coal is necessary, but it does present to the despatcher, yardmaster and roundhouse foreman a splendid field for study in the economy of the use of fuel. They should see that trains move promptly, spending no more time in yards and on sidings than is necessary for safety in operation.

The trainmen should see that equipment and material entrusted to their care is handled to the best advantage and they should put forth every effort to expedite train movements. Four-fifths of all the coal burned in locomotives is consumed while they are actually moving trains. For the use of this fuel the engine crew is largely responsible. If they could save only one per cent. they would use 1,600,000 tons less a year. Their efforts would be greatly enhanced, however, if the equipment were in good condition.

The stationary boilers in shops, pumping stations and heating plants require a large amount of fuel, and present a great opportunity for saving in their construction and operation. This allows the maintenance of way and shopmen to serve in this great conservation program. Telegraph operators and towermen should be alert to clear their trains as soon as it is possible to do so, for every stop a train is obliged to make requires an additional amount of fuel. Conductors and brakemen should see that passenger trains do not become overheated and that cabooses do not burn

more coal than is necessary for the comfort of the crew. Station agents can add their mite by saving a little each month. The efforts of each might seem insignificant, but the sum total would represent an amount that would well merit consideration.

For one reason or another, railroads are often obliged to store out-of-doors a great deal of the coal they use. Sometimes it is done to equalize traffic by using coal cars at a season when they are not in demand by the public, sometimes it is done to forestall shortage due to strikes or other interruptions at the mines; but unless proper care is exercised in the storing of such coal serious loss may result from physical and chemical deterioration.

As the Fuel Conservation Section of the Division of Operation of the U. S. Railroad Administration has given the subject a great deal of special study and attention and has prepared in condensed form a most thorough outline of the methods for conserving coal, the Committee feels that it can do no better than to embody some of its recommendations in this report. Copies of these publications can be obtained by addressing the Fuel Conservation Section at Washington, D. C. Among the recommendations are included the following:

Suggestions for Saving Railroad Fuel.

Publication No. 1. June, 1918.

In our effort to save fuel we must at this time content ourselves with the equipment we have and with the methods with which we are familiar, and rely for our results upon the individual interest and exertion of every man who has to do with the use of railway fuel.

In your effort to help you will find the following suggestions useful. They are not new; they are familiar to all experienced men. They are fundamental to good practice. If every railroad man will bear them in mind and conscientiously apply them in his daily work, enormous savings in fuel will result.

To Railroad Operating Officials:

1. Impress upon every division employee the usual importance of saving fuel.
2. Division Superintendents should hold staff meetings to consider and emphasize fuel economy. They should instruct their staff officers to hold frequent meetings with enginemen, trainmen, and others for the same purpose, using these occasions to give definite instructions and to review fuel performance. The Superintendent's own interest cannot be more effectively shown, nor his influence better exerted, than by his attendance at these meetings.
3. Impress upon all transportation department officials that, under the present fuel shortage, special attention to fuel performance will generally effect greater direct and indirect economies than can be obtained by attention to many less important details of operation.
4. See that fuel statistics are properly analyzed by operating and mechanical department officers, so that improper methods may be promptly corrected.
5. Try to secure the support of enginemen to make economical use of any class of coal which, under existing conditions, the railroads may be compelled to take.

6. Insist that those responsible for the supervision of engineers and firemen closely check their fuel performance, and that they constantly urge upon them the need of following instructions concerning the use of fuel.

7. Increase the supervision of engine crews where necessary and be sure that new firemen receive adequate instruction.

8. Be sure that fuel consumption receives at least as much supervision as is usually given to oil performance. Two scoops of coal are worth nowadays as much as a pint of valve oil.

9. Try to determine the amount of coal which, under careful handling, will be required by road engines for the period between firing up and leaving the terminal, and by yard engines for the entire period of service; and have their actual consumption checked against this average.

10. Adopt a standard size of scoop-shovel. For ordinary conditions the smaller sizes have proven more economical.

11. Provide for your engines sharp, clean, dry sand. A slipping engine wastes fuel, and wears out its machinery and the car draft-rigging.

12. Where possible, run passenger engines over two freight divisions. This reduces coal waste at ashpits and in firing up. Where terminal facilities are limited it has many collateral advantages.

13. If necessary, reorganize your ashpit force so as to provide continuous fire-cleaning service, in order to reduce ashpit delays in waiting to clean fires.

14. Where practicable, old ties, old car material, shavings, etc., should be used to fire up locomotives.

15. Making tests to determine the most economical method of holding engines under steam at outside points—whether by banking the fires or by covering the stack after fires are cleaned.

16. See that engines are not ordered too early and allowed to stand waiting under steam unnecessarily. Work out engine dispatching schedules for freight trains so that engines may be ordered for the scheduled leaving time.

17. Urge upon dispatchers and train crews the necessity of cutting to the minimum all delays on sidetracks and at meeting points.

18. Any avoidable road stop or slowdown wastes coal. Ditspatchers should do their best to keep trains moving, and to put out orders at regular stops. They should promptly take down slow orders when they are no longer necessary.

19. See that yardmasters make up trains with "set-outs" near the head end.

20. Have agents plan their station work before the train arrives.

21. Load locomotives with full tonnage. Underloaded engines waste fuel. A heavy locomotive, running without a train, may itself consume half as much coal as when under load—including terminal consumption.

22. Do not tolerate leaky steam hose connections nor undue drip valve openings on passenger trains.

23. Leaky train line connections, porous or spongy hose, and poor gaskets waste air which is made at the expense of fuel. Every man on a train should do what he can to reduce this loss.

24. Encourage adequate lubrication. Superintendents and car department foremen must see car lubrication from the viewpoint of fuel economy, remembering that there is now only one railroad system and that to pass along defective conditions to a connecting line is neither loyal nor economical. Defective lubrication of engine and car journals causes fuel waste—friction losses begin long before the bearing begins to smoke.

25. The proper maintenance of car trucks and brake gear bears an important relation to fuel economy. See that trucks are kept in good condition and that brake piston-travel is well adjusted.

26. Do not overlook or slight the coal used in stationary power or heating plants at terminals, shops, roundhouses, pump stations and elsewhere. A large share of your fuel is used at these places—and frequently very wastefully used. Your effort here will yield a large return.

27. Lump coal stored at such places as pump houses, shops, stations, banana-sheds, etc., is a constant temptation to theft. Wherever possible use slack or screenings at these points and provide suitable bins.

28. Detail men to check car loading at mines and scale stations.

29. The larger sizes of screenings are most economical for use in locomotive stokers. Try to secure as large a size as your stoker will handle.

30. Instruct enginemen to take as much coal as possible at all mine coaling stations or at stations near the mines. This saves transportation, which in turn saves coal.

31. See that coal-chute aprons are so arranged that coal will not spill from them.

32. Coal spilled at chutes should be promptly picked up—not allowed to lie around until it becomes crushed and dirty.

33. Organize coal chute work so that lumps will be broken to reasonable firing size before they reach the engine.

34. In so far as you can, store coal so as to balance tonnage and reduce empty-car mileage.

35. Choose for storage a quality of coal that will not rapidly deteriorate, and if possible locate storage piles where the coal may be delivered directly to the engines without secondary handling.

36. Coal, when being stored, should be so handled as to be broken as little as possible during the process.

37. Store your coal on clean and level ground, so that it may be picked up again free from dirt.

To Engine House Officials:

38. Have coal shoveled ahead on tenders at terminals remote from the mines, and put on no more coal at such points than is necessary to take the train back to the terminal nearest the mines.

39. Insist that tenders be not so overloaded as to spill coal. Have them trimmed before leaving the chute, so that surplus coal may be picked up.

40. Do not permit locomotives to be held unler steam unnecessarily. If they must be held, bank the fires—if they are to be held for 24 hours remove the fires.

41. Whenever locomotives stand under steam, cover the stacks. A simple sheet iron or wooden cover suffices, and saves heat and coal. If used when fires are dumped, such a stack cover saves heat and reduces boiler maintenance.

42. Do not allow a locomotive to leave the terminal unless its fire is in proper condition.

43. Unless absolutely necessary, do not allow fresh coal to be placed in the firebox while the engine is held for its fire to be knocked.

44. To avoid delay at leaving time, have tools and supplies placed on the locomotive before the crew reports.

45. Maintain firedoor openers so that they will operate properly.

46. Arrange firedoors not equipped with automatic openers so they can be easily swung open and will remain latched open in rounding curves; and so they can be easily swung shut after firing each scoop of coal.

47. Brick arches must be maintained.

48. Remove injectors which are too large. Replace them with those of proper capacity.

49. When locomotive fires are cleaned, have a competent inspector enter the firebox. He should assure himself that the grates are thoroughly clean; that there are no broken grate fingers or excessive openings; that the grate is level when the grate lever keepers are in place and locked, and that the arches are clean and in repair. He should also see that the flues are clean and free from leaks, particularly the superheater flues. Superheater flues when clogged with soot and cinders are useless.

50. See that all coal-burning locomotives have a total ashpan air opening equal to at least 14 per cent. of the grate area.

51. Maintain boilers up to their highest efficiency; wash them when necessary and have the flues bored and blown out every trip. Give special attention to the superheater flues.

52. Do not allow locomotives to run with mud-ring or front-end leaks. This leakage represents a considerable waste of fuel.

53. Make a special inspection of all locomotives to see that the exhaust nozzles are opened up to the largest area consistent with proper steaming. Keep a nozzle record of all locomotives, showing the class, size, date of cleaning, and date of nozzle changes.

54. Holes in the cab decking, defective aprons, and lost motion in the tender connections all lead to direct coal losses.

55. Make certain that steam pipes and superheaters are tested at frequent intervals. Cold water tests should not, however, be made when the parts are hot.

56. See that cylinder and valve rings are maintained so that they do not blow, and keep the valves squared up on all locomotives.

57. On oil-burning locomotives maintain all piping, valves and operating fittings in good condition. Keep the burner clean and in proper alinement, making periodical inspection of burners to determine if defective. Pans must be maintained in good condition and rigidly secured to avoid air leaks at sides and front behind brick work. Inspection should be made each trip to insure brick work being in good condition and all carbon and sand removed. Keep air openings free from slag and carbon accumulations.

58. The flues in an oil-burning boiler require the same attention as a coal burner. Dampers should be maintained over all air openings, and must be easy to operate.

To Locomotive Engineers:

59. If your fireman does not employ the best practice, instruct him yourself and ask the road foreman or locomotive supervisor to have a friendly talk with him, setting him right.

60. Advise the fireman as to grades, shut-off points, the length of time it is probable the train will be held in sidetrack, etc., and explain to him your manner of handling the injector, so that he can anticipate your needs and fire accordingly.

61. Endeavor to work your engine at the shortest practicable cut-off at all times, so as to obtain full benefit of the expansive force of the steam.

62. Endeavor to feed the boiler uniformly, and do not allow the water level to rise so high that the effectiveness of the engine or the superheater will be destroyed.

63. By careful handling, good lubrication of the valves and cylinders can be maintained with a very small quantity of oil. Oil that is fed with steam sticks to the metal surfaces and will lubricate for a long

time unless it is washed off by water or burned off by drifting. If a proper water level is maintained, and attention is paid to the position of the throttle and the reverse lever when drifting, a few drops of oil will protect a large rubbing surface. If, however, in order to cover up errors in judgment, too high a water level is carried when running or if the boiler is overfilled while standing, water from the boiler with its scum and impurities will pass over with the steam and will scour the oil film from the cylinder and valve surfaces. Whenever a high water level does occur, it will prove cheaper to waste some oil than to suffer the friction loss and fuel waste which result from dry valve seats and cylinder walls. Forethought will save both coal and oil, and engineers who make a good fuel performance generally make a good oil performance.

64. Avoid wasting steam at the pops. When conditions, such as emergency stops, making popping unavoidable, close your injector heater cocks and lightly blow steam back into the tank, thus heating the feed water. Injectors will lift water as warm as your hand (100 degrees), and feed water heated to this temperature saves about four per cent. of the fuel and increases the engine's steam capacity on hard pulls.

65. Careful judgment in handling the train brakes will save fuel. A moving train contains energy. Make the best use of this energy consistent with safety. If you lose it by unwise braking, it must be restored through the use of fuel, both for the train and the air pump.

66. Avoid slipping your engine. It tears the fire and wastes coal.

67. Do not use your cab lights or your headlight in the daytime.

To Locomotive Firemen and Hostlers:

68. Close the firedoor after each scoopful of coal is fired.

69. Do not slug the fire. Three or four scoops to a fire, even with the largest engines, has been proved practicable and gives the most economical result.

70. Do not shake the grates except when absolutely necessary—and then shake them gently. They should never be shaken while the engine is working hard; the high draft will then carry ash up into the tubes and superheater flues and clog them.

71. Do not rake the fire, unless it be to fill up a hole or to break down a bank.

72. When your engine is running with a drifting throttle, fire only enough coal to keep the fire in good condition.

73. If large lumps of coal reach your tender, break them down before firing them.

74. Use the blower as lightly as possible, and no longer than is necessary.

75. When entering a terminal let your fire burn down to the proper level; but do not starve it to the point where, in order to get a boilerful of water, it will become necessary to rebuild it just before the engine goes on the cinder pit.

76. Do not use the injector when there is little or no fire in the engine. To do so starts the flues and side-sheets leaking.

77. Keep your deck clean. A well-swept deck with the coal in the tender sprinkled, but not flooded, helps save coal and increases your comfort.

78. Do not permit coal to fall off the gangway. This is not only wasteful, but dangerous.

79. Study the methods of good firing. Talk about them with other firemen. Try to improve your own practice.

80. On oil-burning locomotives sand the flues frequently; save oil by avoiding black smoke.

81. Whether using coal or oil, persistent black smoke indicates poor firing. Try at all times to avoid, but especially in cities, where it causes not only fuel waste, but discomfort and damage.

SUGGESTIONS FOR SAVING RAILROAD FUEL AT STATIONARY PLANTS.

Fuel Conservation Circular No. 14. September 25, 1918.

In order to avoid repetition, the suggestions are grouped below, first, with respect to Plant Design and Equipment; second, with respect to Maintenance; and third, with respect to Operation. Under the heads of Design and Equipment, and Maintenance, the suggestions are further divided; first, with respect to power and heating systems; and third, shop equipment. Under the head of Operation they are divided with respect to power and heating plants, and to miscellaneous uses. Under each of the three main headings, unless otherwise specifically so stated, the suggestions have been made with the larger power plants in view, and some of them are consequently but little applicable to smaller installations. Most of them, however, are applicable in some degree to the small isolated plants.

The suggestions are intended to cover all forms of energy production and distribution to be met with in railway plants, and they relate to practices which may affect, either directly or indirectly, the consumption of fuel.

Plant Design and Equipment.

1. Responsible operating officials should insist on a review of conditions at all stationary plants, and should give careful consideration to the feasibility of making desired improvements.

2. It is recommended that some person or a committee be charged with special responsibility for the conservation of fuel in this field, and that their other work be so arranged that they may devote adequate attention to this duty. It is chiefly because such responsibility has been incidental to many other duties that railway stationary plants have continued as inefficient as they are.

3. One of the first requirements for improvement is a knowledge of existing conditions and performance, and for this reason the recommendations given below concerning coal records, water records, gas analysis and similar matters are important.

4. At staff meetings and upon other occasions operating officials should impress upon all concerned the importance of fuel conservation in this field, remembering that in this, as in all other matters, continued interest and effort can be sustained only from the top of the organization. Communications and instructions on this subject should be steadily followed up to remove the prevailing indifference toward what are regarded as trifling losses.

5. Since under present conditions widespread changes in equipment may not be made, it is obvious that the chief return is to be had through improved maintenance and operation. While effort at these two points is easy to set in motion, it can be sustained only by persistent following up; and adequate supervision must be provided.

6. To railroad men coal is a common commodity. Most of them see thousands of tons of it every day. This fact makes it difficult for them to realize the present shortage of fuel and the necessity for the strictest economy in its use. It is especially difficult to realize this need in connection with the use of small quantities of coal, such as the few bushels which a station agent may use in the course of a day. But it is in these

small uses that practice is most wasteful, and everyone must understand that no saving is too small to merit his attention. Some person or some industry may be in desperate need of the fuel which can be saved at these points.

7. At many small and inefficient power and pumping plants it would prove cheaper to buy power or to buy water than to continue to operate the generating plant. Projects of this sort, which in previous years may have been under consideration, should be reviewed. Under the present price of fuel it may now prove profitable to discontinue the production of power at such places, and it is likely in every instance to result in fuel savings.

8. The old discarded locomotive boiler makes a wasteful and extravagant heating plant. It should be displaced as rapidly as possible.

9. One of the chief sources of loss in steam boilers is excessive air supply, resulting from excessive door and ashpit openings, boiler-settling air leaks, and excessive draft. The CO_2 recorder offers one of the best means for discovering excess air and improper combustion, and its cost of installation will be amply repaid in plants of any considerable size.

10. Determine the air pressure of the furnace with draft gages connected with the furnace or breechings. They eliminate guesswork and insure a proper air supply for combustion. Regulate the draft on all of the boilers with the main flue damper, after settling the individual dampers on each. Check the combustion by analyzing the flue gases. Suitable instruments are available at from $15 to $25. By this method admission of excess air may be readily detected, the skill of the fireman known, and waste of fuel prevented.

11. Whenever it is feasible to do so, boiler feed-water should be heated, using exhaust steam for that purpose. One per cent. saving of fuel results for each 10-degree rise in temperature of the feed-water.

12. The first requisite to efficient operation is a knowledge of the amount of coal consumed; and, wherever it is possible, provision should be made for weighing the coal used during each shift or during each day. Records of daily consumption should be made and periodically reviewed. In small plants, where weighing is impracticable, the coal consumed may be occasionally estimated by counting the number of scoops used during a given period.

13. The boiler feed-water should be similarly measured and recorded for each shift or for each day, wherever it is feasible to do so.

14. See that the valves and the valve motions on your steam engines and air compressors are gone over and put in good condition. Engines and compressors that have run for years without thorough adjustment are sure to be wasting steam.

15. Enormous losses occur from condensation in transmission lines. The surfaces of all steam piping, drums, and feed-water heaters, which waste heat by radiation, should be properly covered with insulating material. Four-fifths of the radiation loss can be avoided by covering these surfaces with 85 per cent. magnesia, or similar material, two inches thick. Especially serious losses of this sort occur in poorly protected underground steam lines through yards. All such piping should be insulated with great care. Suitable traps should be maintained on all radiating systems.

16. Group your shop machines so that the driving motors or engines operate at their point of highest efficiency.

17. Eliminate the operation of shop motors when machines are idle. Shopmen will do this if switches are conveniently placed.

Maintenance.

18. Records should be kept of boiler and power plant maintenance as well as records of operation. If someone is made personally responsible for the physical condition of furnaces, boilers and engines, and signed reports are required from him at regular intervals, the condition of the plant will not be likely to deteriorate.

19. All air leakage into the boiler should be stopped. Badly warped or cracked fire doors should be repaired or replaced, and air leaks in the brick work or boiler setting should be stopped. Such leaks can be found by holding a lighted torch to the parts under suspicion and by watching to see if the flame is drawn in by the draft. They may be conveniently stopped by caulking into the openings cord or sheet asbestos made plastic by water.

20. It is important also that leaks in brick arches and in interior brick work be stopped in like manner. Such leaks not only permit the short-circuiting of the gases, but they conduce to the leakage of outside air by causing the exterior brick setting to become overheated.

21. Keep the grates in repair. Burned out and broken grates waste coal into the ashpit and permit the passage of surplus air, causing holes in the fire and clinkers.

22. All boilers should be thoroughly washed out at short and regular intervals. Suitable hose, rods, and scrapers must be supplied for this purpose. Particular attention should be given to the crown sheet and water leg in locomotive-type boilers, and, in return tubular boilers, to the lower portion and to the back ends of the flues, where mud is most likely to accumulate. Where water of inferior quality must be used, provision for treating it before it enters the boiler should be made if possible. In emergencies or when the volume of water is too small to justify an independent treating plant, a properly prepared boiler compound will be of assistance.

23. It is just as necessary to clean the soot and ash from the heating surfaces of stationary boilers as it is to blow and bore the flues in the locomotive. Boiler surfaces should be regularly cleaned and, even under favorable circumstances, should not be allowed to go more than 12 hours without being blown down. Where compressed air is not available, use dry steam for this purpose. In addition, a flue cleaner should be frequently run through the entire length of the tubes.

24. Most railroad shops and yards have extensive pipe lines for the transmission of steam, water, and air—many of them placed under disadvantageous circumstances. The aggregate fuel loss due to leakage from such pipe lines is one of the greatest losses in this field, and special effort should be made to eliminate it. Make provision to inspect regularly and stop the leaks in the steam lines around your shops and through the yards. Underground steam lines through yards are apt to be in especially bad condition. Watch carefully the leakage in your compressed air lines; it wastes a great deal of power. Cut down water wastes caused by leakage and carelessness, and reduce the use of hot water to a minimum.

25. See that all shafting and transmission mechanism is properly maintained. Bearings should be regularly oiled and inspected for correct alinement, and belts should be inspected to prevent slippage.

26. From heated buildings or buildings where steam is generated or consumed, there are frequently great heat losses by direct leakage of warm air. In all such boiler-houses, shops, roundhouses and other buildings overhaul the doors, windows and other openings, restore broken glass, and otherwise make them tight, in order to cut down this loss.

Operation.

27. Too many railroad stationary plants are operated by unskilled men. The attempt to save money by employing inexperienced labor at such places is almost certain to defeat its own end. It should be so designed and operated that no more exhaust steam is produced than can be used.

28. Wherever possible use exhaust steam instead of live steam direct from the boiler. So far as possible the plant should be so designed and operated that no more exhaust steam is produced than can be used.

29. Some shops, most office buildings, and practically all stations are kept unreasonably hot in cold weather. Thermometers should be provided in all such places, and somebody should be charged with the responsibility of seeing that the temperature is kept down to a reasonable limit. Sixty-five degrees is generally enough and is much more comfortable and healthful than a higher temperature. In offices 68 degrees Fahrenheit should be the maximum temperature; and for shops and other buildings where clerical labor is not required, 60 degrees Fahrenheit is sufficient. All unused radiators or those in excess of the requirements should be disconnected.

30. Shop and roundhouse lighting must, of course, be adequate for the comfort and safety of the men, but considerable power and fuel may be saved by strict attention to lighting wastes. Lights should be turned off when not in use. In many situations the candlepower of lights may be reduced without inconvenience to anyone. Carbon filament lamps should be replaced by those of later and more efficient type, and arc lamps in many situations should be abandoned for large lighting units of more efficient type.

31. Shop operations may frequently be so arranged as to avoid concentration of load. Thus to stagger shop operations so as to avoid peaks in the load may save considerable fuel.

32. Eliminate the open coal basket and the open coal fire, which are frequently found at ashpits and water cranes. Inexpensive enclosed sheet steel stoves can be used at such places.

33. Lump coal stored at such places as pumphouses, shops, stations, and banana sheds, etc., is a constant temptation to theft. Wherever possible, use slack or screenings at these points and provide suitable bins.

34. Wood is good fuel, and railroads frequently have available large amounts of waste wood, such as ties or car shop scrap. Use this wood in place of coal or oil wherever possible.

FUEL CONSERVATION CIRCULAR No. 13.

To Superintendents, Motive Power and Car Department Officials, Men in Charge of Car Maintenance, Yardmasters and Switchmen, Conductors and Trainmen:

Appreciating the country's present urgent need for the conservation of fuel, the Air Brake Association, through its President, F. J. Barry, and its Secretary, F. M. Nellis, recently tendered to the Fuel Conservation Section of the United States Railroad Administration the assistance of the association in the work of conserving fuel. Following this offer, a committee of supervising air-brake representatives from 24 of the largest rail lines in the country met in Chicago on July 31 for the purpose of drawing up such concise recommendations concerning air-brake maintenance as would effect material economies in railway fuel.

This committee, after careful and deliberate study of the air-brake situation, announced that the leakage of air in brake pipes and con-

nections under freight cars was responsible for an annual loss of over 6,000,000 tons of coal. With the exception of train-line losses incurred in controlling trains on heavy descending grades, it is estimated that 95 per cent. of the fuel consumed in compressing air on locomotives is used to make good this brake-pipe leakage.

The committee also stated that in their opinion the railroads could quickly and without much additional operating expense greatly reduce this loss; and they submitted certain recommendations for the consideration of railway operating officials and employees.

Specific tests have shown that a train-pipe leakage of seven pounds per minute on a 50-car train entails a loss of more than 39 cubic feet of free air per minute, and absorbs 91 per cent. of the capacity of one 9½-inch pump, or 59 per cent. of the capacity of one 11-inch pump. Under conditions that frequently prevail on 50-car trains the brake-pipe leakage often amounts to more than double the quantities stated.

The recommendations submitted by the special committee for the prevention of these extraordinary losses are as follows:

1. In switching cars in hump yard service, hand brakes must be known to be in operative conditions before dropping over the hump. Each cut should be ridden home and must not be allowed to hit cars on make-up track at a speed exceeding three miles per hour, as excessive shocks result in loosened brake-pipe and cylinder connections with attendant leakage at joints. The same conditions apply to general yard switching and similar care should be exercised.

2. When hose are uncoupled they must be separated by hand and not pulled apart. Pulling hose apart is not only the most prolific cause of brake-pipe leakage, but the damage annually due to train parting on account of hose blowing off nipples or bursting due to fiber stress runs into thousands of dollars. Angle cocks first must be closed if brake-pipe is charged.

3. Ample time must be allowed to properly inspect the air brakes and place them in good working order before leaving terminals.

4. Freight terminals, where conditions and business handled justify the installation, should be provided with a yard-testing plant, piped to reach all outbound trains. At all freight houses, loading sheds, team tracks and other places where cars in quantity are spotted for any purpose long enough to make repairs and test brakes, air should be provided to do such work.

5. On shop and repair tracks provided with air, brakes should be cleaned and tested in accordance with M. C. B. rules and instructions. Weather permitting, hose and pipe connections shall be given soapsuds test. Hose showing porosity shall be removed and all leaks eliminated before car is returned to service.

6. Freight trains on arrival at terminals where inspectors are stationed to make immediate brake inspection and repairs, shall have slack stretched and left with brakes fully applied.

7. Brake-pipe leakage on outbound freight trains shall not exceed eight pounds per minute, and preferably should not exceed five pounds per minute, following a 15-pound service reduction from standard brake-pipe pressure with brake valve in lap position.

8. A suitable pipe wrench should be furnished each caboose to enable trainmen to remove and replace hose and to tighten up leaks developing en route. Instructions directing its use should be posted in each caboose.

9. A rule should be put into effect that trainmen must apply an M. C. B. standard air-brake defect card in cases where defects develop enroute or for brakes cut out by them; defect to be checked off on back of card.

10. Air-compressor strainers must be known to be free of foreign matter before each trip and removed for cleaning, if necessary. The steam pipe to compressor shall be lagged outside of cab or jacket.

11. Special effort must be made to reduce the leakage of the various air-operated devices on locomotives.

12. In mounting air hose, the coupling should be gaged with an M. C. B. standard gage, and the couplings and coupling packing-rings known to be standard.

13. Special attention should be given to maintaining brake-pipe, brake cylinder, reservoir, retaining valves, and pipe secure to car.

14. The importance of competent air-brake supervision to successfully cope with existing conditions can not be overéstimated.

15. In the recommendations submitted it is not the intent in any way to abrogate existing instructions or rules now in force, which are more stringent than those recommended.

Appendix B.

CONSERVATION OF FUEL IN CANADA IN 1918.

As a result of the War, the cost of fuel in Canada, particularly coal, was much enhanced and a fuel shortage was, for a time, almost a certainty. These considerations forced Canadians to adopt a policy of conservation and necessitated the abandonment of the old policy of *laissez faire* that has been so detrimental to their material interests. Canadians are, at last, recognizing that no natural resources are "illimitable" or "inexhaustible," particularly as regards mineral fuels such as coal, which, once exhausted, can never be replaced.

The high prices and the heavy demands for munition plants and other industries connected with the war have greatly stimulated the production of coal in Saskatchewan and Alberta. On the other hand, the enlistment of miners and the high wages paid in munition plants has resulted in decreased production in Nova Scotia and British Columbia.

In 1917 Canada imported from the United States 15,537,262 tons of bituminous and 5,320,198 tons of anthracite, as compared with Canada's domestic production, namely, 11,154,251 tons of bituminous, 2,784,283 tons of lignite and 108,225 tons of semi-anthracite.

Canada is, therefore, practically dependent upon the United States for her supply of anthracite coal, the one mine in the Dominon producing semi-anthracite, near Banff, Alta., having a total production of only 103,-225 tons in 1917. As the anthracite coal allotted to Canada during the year 1918-19 by the United States Fuel Administrator is 23 per cent. less than Canada received during the coal year 1917-18, consumers have been forced to resort to other fuels to supply the deficiency. In practice, this means that either bituminous, lignite or wood must be used during the current winter to supplement the limited amount of anthracite available. Dismayed at being forced to use these substitutes, consumers are directing attention to the various methods whereby coal can be converted into fuel possessing most of the advantages of anthracite.

The first and most readily available substitute for coal is, of course, wood fuel. Its use is a practical measure of conservation, if only because it has one advantage as compared with coal, namely, that, if protected from fire, it reproduces itself without labor or monetary cost. Large quantities of wood have been cut, particularly in Quebec, Ontario and Manitoba.

Much attention has been devoted to the utilization of peat, but, for various reasons, principally the high cost of labor and the comparatively low price of the product if marketed to compete with coal, no peat was produced in Canada in 1917 or 1918. Although 97,363 short tons of peat was produced in the United States in 1917, most or all of this production was used as a fertilizer, as a filler for chemical fertilizers, as an ingredient of stock food, or was used by florists. The fact that it was sold at an average price of $7.29 per short tone demonstrates that, at the present

time, peat cannot compete with coal in the United States, nor could it compete in Canada if its cost approximated the figure above quoted.

As a means of conserving coal, the greater utilization of Canada's water powers, particularly in coalless central Canada, has been strongly urged. It is highly probable that, in the near future, the development of some, at least, of the great powers of the St. Lawrence will be undertaken. In the portion of the river traversed by the international boundary the development should, and probably will, be undertaken by the governments of Canada and the United States jointly.

Every pound of coal saved by the use of water-power is a pound conserved for posterity, whether the power be used directly or for the generation of electric energy and subsequent use of same for power. The method of distribution is not important so long as the generating plants and the rates charged by the distributing companies are controlled by the two Governments. While an excess of electric energy for which no other market could be obtained might be used for electric heating of houses, etc., it has been demonstrated by Arthur V. White that, with anthracite at $10.00 per ton and electric energy at one cent per kilowatt hour, electric heating is four times as costly as with coal.

Anthracite has steadily increased in price year by year. This, and the fact that, if production continued at the present rate, the anthracite in the United States would be exhausted in less than a century, demonstrate that, ere long, none but the well-to-do will be able to afford it. Recognizing this, the Canadian Commission of Conservation has been urging the increased utilization of bituminous coal and lignite. They have urged the advantages of central cooking plants, whereby all the products, namely, coke, gas and tar, can be utilized, and have pointed out the advantages of carbocoal, which has been used successfully in England. It is probable that such plants will be established in the near future in the vicinity of some of the larger cities, and their success will induce the construction of similar plants elsewhere.

The Canadian Commission has also advocated the use of pulverized coal in certain metallurgical processes in cement plants, in locomotives and in other uses which have been demonstrated to be economical. During the year the British Columbia sugar refinery in Vancouver, B. C., installed the first equipment in Canada to use pulverized coal.

The sum of $200,000 has been granted by the Federal Government and $100,000 each has been granted by the governments of Manitoba and Saskatchewan for the construction of an experimental plant to produce carbonized lignite briquettes. If this plant is successful in producing a product that can compete with anthracite, it will demonstrate the possibility of utilizing the enormous amount of lignite that underlies a large part of Saskatchewan and Alberta, particularly the lignite of the Souris district in Saskatchewan, which is very advantageously situated with reference to the fuel market.

Appendix C.

PEAT AS FUEL.

The Committee on Conservation of Natural Resources suggests that thorough investigation be made with a view to using the vast muskeg or peat deposits in the northern part of the United States as fuel to alleviate the present stress in the fuel situation. It is our opinion that, if properly handled, this material could be used for domestic supplies in factories where boilers with considerable grate areas could be arranged.

This material will, of course, require some preparation in the way of drying and pressing to make it suitable for fuel. Steps are already being taken to use some of the muskeg mosses as surgical dressings, and there is no doubt but what many other uses could be found for this material, such as insulating and deadening in buildings, substitute for excelsior for packing, etc.

As the matter now stands, these deposits are wholly undeveloped and are for the most part barren waste, notwithstanding the fact that by suitable drainage and tilling very valuable agricultural lands could be produced.

REPORT OF COMMITTEE XVII—WOOD PRESERVATION.

C. M. TAYLOR, *Chairman;*
DR. HERMANN VON SCHRENK, *Vice-Chairman;*
F. J. ANGIER,
F. L. C. BOND,
E. H. BOWSER,
W. A. FISHER,
C. F. FORD,
C. J. GRAFF,
R. H. HOWARD,
C. H. R. HOWE,
J. E. JOHNSON,
G. E. REX,
LOWRY SMITH,
O. C. STEINMAYER,
H. STEPHENS (in Military Service),
E. A. STERLING,
C. H. TEESDALE,
J. H. WATERMAN,

Committee.

To the American Railway Engineering Association:

Your Committee on Wood-Preservation respectfully submits its report to the Twentieth Annual Convention.

The following subjects were assigned to your Committee by the Board of Direction:

1. Make critical examination of the subject-matter in the Manual, and submit definite recommendations for changes, with especial reference to the subject-matter of "Water in Creosote."

2. Report on the compilation of service test records and extend them to include treated timbers in bridges, docks and wharves. Include also a critical study of the records of service given by the zinc-chloride treatment and state definitely the results which may be obtained from that treatment.

3. Report on the merits of water gas tar as a preservative, taking samples of the preservative from timbers which have been in service, in order to determine its quality.

4. Co-operate with similar committees of other associations with the object of obtaining uniformity in practice and specifications, and report thereon.

5. Report on preservative treatment for Douglas fir.

6. Report on indicators for determining the Burnettizing of ties and timbers.

COMMITEE MEETINGS.

Meetings of the whole Committee were held in Chicago on July 16, in Madison on October 10, and in Baltimore on December 11; in addition to these, meetings of the various Sub-Committees were held, most of which the Chairman was able to attend.

(1) REVISION OF MANUAL.

Proposed changes or additions to the Manual are indicated by underscored lines in the appendices.

In Appendix A the Committee submits changes and additions on the following items and recommends their adoption under the heading of Conclusions:

(a) Revised specifications for creosote oil.

(b) Revised specification for creosote-coal-tar solution.

(c) Revised title to include creosote-coal-tar solution with creosote oil under methods for determining absorption.
(d) Revised wording and fuller details in the analysis of creosote oil.
(e) Revised specification for Zinc Chloride.
(f) New specification covering the method for determining the strength of zinc chloride solution.

(2) TEST RECORDS TO INCLUDE BRIDGES, DOCKS AND WHARVES. ALSO RECORDS OF ZINC CHLORIDE TREATMENT AND THE RESULTS WHICH MAY BE OBTAINED THEREFROM.

In Appendix B the Committee submits information concerning creosoted water tanks.

The Committee also submits the results of a very thorough investigation of the Burnettizing treatment and submits for information general conclusions relative to the value of Zinc Chloride, Creosote Oil and as mixture of the two.

It submits a revised specification for the treatment of ties by the Burnettizing Process, which is recommended for adoption under the heading of Conclusions.

(6) INDICATORS FOR DETERMINING THE PENETRATION OF ZINC CHLORIDE IN TIES AND TIMBERS TREATED BY THE BURNETTIZING PROCESS.

In Appendix C, the Committee submits as information an improvement of the Bateman method as proposed by the Forestry Service.

PROGRESS REPORT.

The Committee reports progress on subjects (3) Water Gas Tar as a preservative; (4) Uniformity of practice and specifications with other associations; (5) Douglas Fir preservative treatment.

CONCLUSIONS.

Your Committee makes the following recommendations to the Association:

For Adoption and Publication in the Manual.

Subject (1)

(a) Proposed revision of specifications for Creosote Oil.
(b) Proposed revision of specification for Creosote-coal-tar solution.
(c) Proposed revision of title to include Creosote-coal-tar solution with Creosote Oil under methods for determining absorption.

(d) Proposed revision of wording and fuller details in the analysis of Creosote Oil.

(e) Proposed revision of specification for Zinc Chloride.

(f) Proposed specification covering method for determining the strength of Zinc Chloride solution.

Subject (2) Proposed revision of specification for treatment of ties by the Burnettizing Process.

Accept as Information.

Subject (2) Report on the creosoting of water tanks.

Report on the question of the treatment of ties with Zinc Chloride and the general recommendations and conclusions in connection therewith.

Subject (5) Report covering improved method for determining visually the penetration of ties treated with Zinc Chloride.

RECOMMENDATIONS FOR FUTURE WORK.

Your Committee recommends for next year's work: Continuation of Subjects (1), (2), (3), (4), (5), (6), and as new subjects:

(1) Availability and use of Sodium Fluoride as a Preservative for Cross-Ties.

(2) Creosote treatment to be used in the protection of piles in teredo infested water.

Respectfully submitted,

THE COMMITTEE ON WOOD PRESERVATION.

Appendix A.

REVISION OF MANUAL.

Sub-Committee: DR. H. VON SCHRENK, Chairman; F. J. ANGIER, W. A. FISHER, C. J. GRAFF and C. M. TAYLOR.

The Committee reports that a joint committee consisting of representatives of the Preservative Committee of the American Wood-Preservers' Association and of this Committee conducted a further investigation on the question of "Water in Creosote" with special reference to the water content of oil shipped in tank cars and the sampling of such cars before being unloaded. The work to date strengthens our belief that the Zone Sampling Method, adopted as standard practice (see Vol. 18, A. R. E. A. Proceedings, page 1271), is correct in principle, but that it needs a further refinement for actual application. The Committee suggests that this co-operative work be continued until the method is definitely determined for all conditions.

The Committee, after a study of the specifications for creosote oil and creosote-coal-tar solution, finds that the specifications adopted in 1912 should be revised. This revision is necessary because increased safe-guards have been developed for enforcing the specifications. The specifications herewith recommended are the result of several years' work of committees of the American Railway Engineering Association, American Wood-Preservers' Association and American Society for Testing Materials. The three revised specifications differ from the specifications now printed in the Manual only in the addition of certain clauses to make the specifications more workable.

STANDARD SPECIFICATION FOR CREOSOTE OIL.

The oil shall be distillate of coal-gas or coke-oven tar. It shall comply with the following requirements:

1. It shall contain not more than 3 per cent. of water.

2. It shall contain not more than 0.5 per cent. of matter insoluble in benzol.

3. The specific gravity of the oil at 38°/15.5° C. shall be not less than 1.03.

4. The distillate, based on water-free oil, shall be within the following limits:

Up to 210 degrees Centigrade not more than 5 per cent.

Up to 235 degrees Centigrade not more than 25 per cent.

5. The specific gravity of the fraction between 235 degrees Centigrade and 315 degrees Centigrade shall not be less than 1.03 at 38°/15.5° C.

The specific gravity of the fraction between 315 degrees Centigrade and 355 degrees Centrigrade shall not be less than 1.10 at 38°/15.5° C.

6. The residue above 355 degrees Centigrade, if it exceeds 5 per cent., shall have a float test of not more than 50 seconds at 70 degrees Centigrade.

7. The oil shall yield not more than 2 per cent. coke residue.

8. The foregoing tests shall be made in accordance with the standard methods of the American Railway Engineering Association.

In addition to the oil conforming to the above standard specification, the two grades specified below may be used when the higher grade oil cannot be procured:

Specification for Grade 2 Creosote Oil.

The oil shall be a distillate of coal-gas or coke-oven tar. It shall comply with the following requirements:

1. It shall contain not more than 3 per cent. of water.

2. It shall contain not more than 0.5 per cent. of matter insoluble in benzol.

3. The specific gravity of the oil at 38°/15.5° C. shall be not less than 1.03.

4. The distillate, based on water-free oil, shall be within the following limits:

Up to 210 degrees Centigrade not more than 8 per cent.

Up to 235 degrees Centigrade not more than 35 per cent.

5. The specific gravity of the fraction between 235 degrees Centigrade and 315 degrees Centigrade shall be not less than 1.03 at 38°/15.5° C.

The specific gravity of the fraction between 315 degrees Centigrade and 355 degrees Centigrade shall be not less than 1.10 at 38°/15.5° C.

6. The residue above 355 degrees Centigrade, if it exceeds 5 per cent., shall have a float test of not more than 50 seconds at 70 degrees Centigrade.

7. The oil shall yield not more than 2 per cent. coke residue.

8. The foregoing tests shall be made in accordance with the standard methods of the American Railway Engineering Association.

Specification for Grade 3 Creosote Oil.

The oil shall be a distillate of coal-gas or coke-oven tar. It shall comply with the following requirements:

1. It shall contain not more than 3 per cent. of water.

2. It shall contain not more than 0.5 per cent. of matter insoluble in benzol.

3. The specific gravity of the oil at 38°/15.5° C. shall be not less than 1.03.

4. The distillate, based on water-free oil, shall be within the following limits:

Up to 210 degrees Centigrade not more than 10 per cent.

Up to 235 degrees Centigrade not more than 40 per cent.

5. The specific gravity of the fraction between 235 degrees Centigrade and 315 degrees Centigrade shall not be less than 1.03 at 38°/15.5° C.

The specific gravity of the fraction between 315 degrees Centigrade and 355 degrees Centigrade shall not be less than 1.10 at 38°/15.5° C.

6. The residue above 355 degrees Centigrade, if it exceeds 5 per cent., shall have a float test of not more than 50 seconds at 70 degrees Centigrade.

7. The oil shall yield not more than 2 per cent. coke residue.

8. The foregoing tests shall be made in accordance with the standard methods of the American Railway Engineering Association.

It is urged that when Grades 2 or 3 are used, consideration be given to the injection of a greater quantity of creosote oil per cubic foot.

Specifications for Creosote-Coal-Tar Solution.

The oil shall be a coal-tar product, of which at least 80 per cent. shall be a distillate of coal-gas or coke-oven tar, and the remainder shall be **refined or filtered coal-gas or coke-oven tar. It shall comply with the following requirements:**

1. It shall contain not more than 3 per cent. water.

2. It shall contain not more than 2 per cent. of matter insoluble in benzol.

3. The specific gravity of the oil at 38 degrees / 15.5 degrees Centigrade shall not be less than 1.05 nor more than 1.12.

4. The distillate, based on water-free oil, shall be within the following limits:

Up to 210 degrees Centigrade not more than 5 per cent.

Up to 235 degrees Centigrade not more than 25 per cent.

5. The specific gravity of the fraction between 235 degrees Centigrade and 315 degrees Centigrade shall not be less than 1.03 at 38°/15.5° C.

The specific gravity of the fraction between 315 degrees Centigrade and 355 degrees Centrigrade shall be not less than 1.10 at 38°/15.5° C.

6. The residue above 355 degrees Centigrade, if it exceeds 26 per cent., shall have a float test of not more than 50 seconds at 70 degrees Centigrade.

7. The oil shall yield not more than 6 per cent. coke residue.

8. The foregoing tests shall be made in accordance with the standard methods of the American Railway Engineering Association.

Your Committee recommends that the precaution pertaining to inspection and precautions in the use of the creosote-coal-tar solution, as now appearing in the Manual, be changed to read as follows:

PRECAUTIONS TO BE FOLLOWED IN THE PURCHASE AND USE OF THE CREOSOTE-COAL-TAR SOLUTION.

1. The specifications for a creosote-coal-tar solution is submitted for the guidance of those desiring to use the coal tar addition to creosote.

2. There should be a distinct understanding between all concerned that a mixture is specified and used.

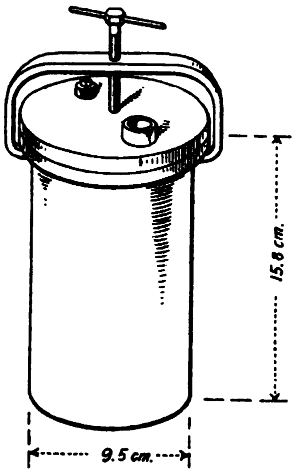


FIG. 1—COPPER STILL.

3. The refined coal-tar used shall be subject to inspection or analysis by the railway company at any time, such examination to be permitted upon request prior to the mixing of the solution.

4. In case the railway company makes its own solution of coal-tar and creosote, using crude tar for this purpose, it shall specify clearly as to the quality of the tar. Only low carbon coal-tar should be used, the amount of free carbon not to exceed 5 per cent.

5. The coal-tar may be added to the creosote at treating plants when suitable facilities for properly mixing the solutions are available, otherwise the solution should be mixed by the manufacturer, but subject to the inspection or supervision of the railway company. The coal-tar and creosote should be thoroughly mixed at a temperature of approximately 180 degrees Fahrenheit before being applied to timber. The mixing

should be done in tanks other than the regular working tanks, and the tanks containing the mixture should be heated and agitated thoroughly each time before any oil is transferred to the working tanks.

6. In treating with the mixture the temperature of the solution in the cylinder should not be less than 180 degrees Fahrenheit.

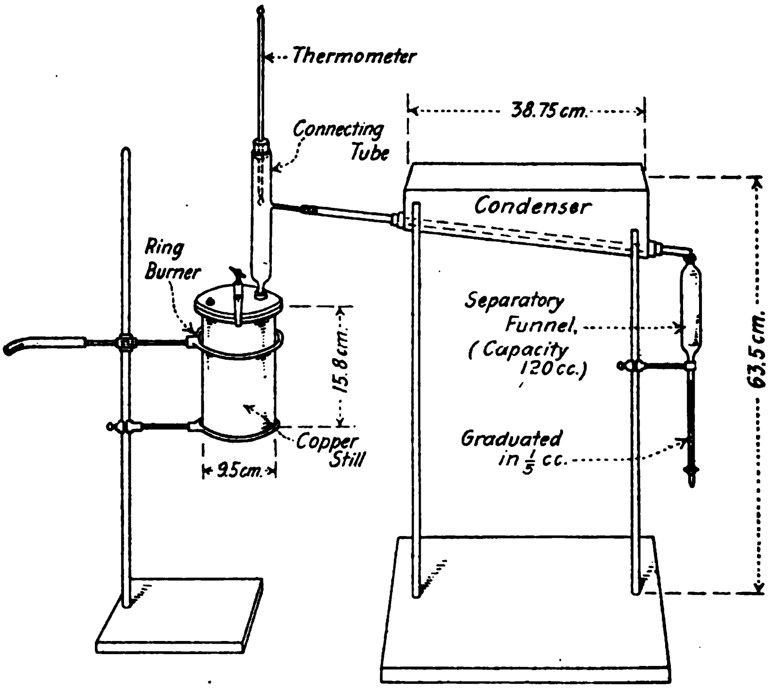


Fig. 2—Assembled Apparatus for Water Test.

Your Committee further recommends that the title on page 548, 1915 Manual, dealing with methods for determining absorption, now reading "Methods of Accurately Determining the Absorption of Creosote Oil," be changed to read "Methods of Accurately Determining the Absorption of Creosote Oil and Creosote-Coal-Tar Solution."

Analysis of Creosote Oils.

Since the adoption of the revised standard methods for analysis of creosote oil, as printed in the Supplement to the Manual, July, 1917, Bulletin 197, and as a result of co-operative work between committees of

this Association, American Wood-Preservers' Association, and the American Society for Testing Materials, certain slight corrections, changes and additions have been made. Your Committee, therefore, recommends that these be embodied in the standard specifications for creosote analysis.

Under paragraph 1, "Water," change the description for the apparatus as follows:

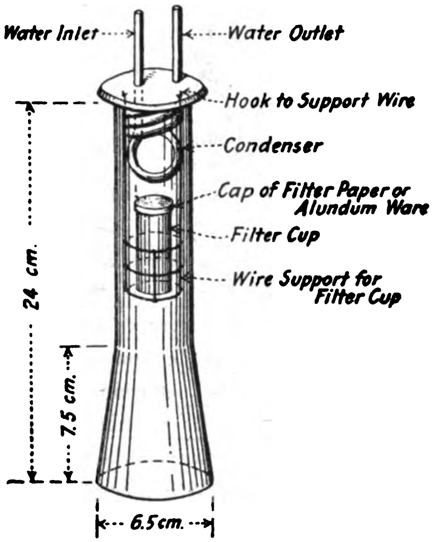


Fig. 3—Extraction Flask.

A vertical, cylindrical copper still, with removable flanged top, and yoke, of the form and approximate dimensions shown in Fig. 1, shall be used.

In Fig. 2 add dimensions and explanatory words to the various parts of the apparatus, as per attached drawing.

In Fig. 3, illustrating the extractor, add dimensions, as per attached drawing.

In Section 3, Specific Gravity, under Apparatus, add: (c) If a very accurate method is desired, the specific gravity may be determined by means of a pycnometer or specific gravity bottle, as shown in Fig. 6, having a capacity of at least 25 cubic centimeters.

Under Method add: (a) in front of the hydrometer method, and after the words "unnecessarily high temperature" add the following paragraph:

"Before taking the specific gravity, the oil in the cylinder should be stirred thoroughly with the glass rod, and this rod, when withdrawn from the liquid, should show no solid particles at the instant of with-

drawal. Care should be taken that the hydrometer does not touch the sides or bottom of the cylinder when the reading is taken, and that the oil surface is free from froth and bubbles."

Also add (b): Weigh the pycnometer empty, then fill with recently distilled water and weigh at 38 degrees Centigrade. Empty the pyc-

FIG. 6—PYCNOMETER.

nometer and then fill with water-free oil at 38 degrees Centigrade, and weigh. The specific gravity 38°/15.5° C. is then calculated as below:

The expression "38 degrees / 15.5 degrees Centigrade" means specific gravity taken at 38 degrees Centigrade compared with water at 15.5 degrees Centigrade. This cannot be determined directly. The specific gravity is first determined at 38 degrees Centigrade compared with water at 38 degrees Centigrade, and this determination represents the relation of the weight of a volume of oil at 38 degrees Centigrade to the weight of an equal volume of water at the same temperature. The relation to an equal volume of water at 15.5 degrees Centigrade is obtained by multiplying the former figure by .99385, the density of water at 38 degrees Centigrade compared to water at 15.5 degrees Centigrade.

From the foregoing it will be readily seen that it is incorrect to calculate the specific gravity at 38°/15.5° C., by dividing the weight of oil taken at 38 degrees Centigrade by the weight of water taken at 15.5 degrees Centigrade. An example is given herewith of the correct and incorrect methods of calculating; where the weight of a specific gravity bottle is 23.7531, the weight of the bottle filled with water up to the mark at 15.5 degrees Centigrade is 78.3600; the weight of the bottle plus water at 38 degrees Centigrade is 78.1128; the weight of the bottle filled with oil at 38 degrees Centigrade is 80.2755. The correct calculation, therefore, would be as follows:

Specific gravity at 38°/15.5° C.—

$$\frac{80.2755 - 23.7531}{78.1128 - 23.7531} - 1.0398$$

Corrected to 38°/15.5° C.—

$$\frac{1.0398 \times .99299 \text{ (D. water 38 degrees)}}{.99913 \text{ (D. water 15 degrees)}} — 1.0335$$

The incorrect method of calculation is as follows:

$$\frac{80.2755 — 23.7531}{78.3600 — 23.7531} — 1.0351.$$

Fig. 7. Add dimensions as per attached drawing.

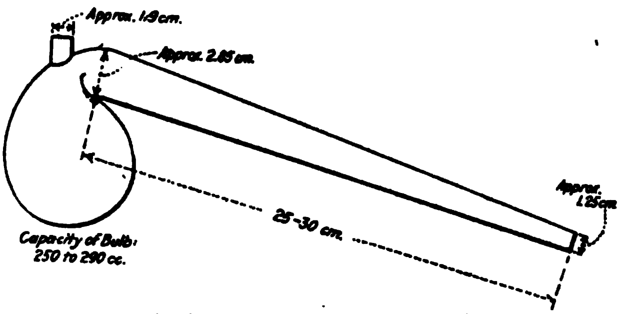


Fig. 7—Retort for Distillation Test.

Change Fig. 7 to Fig. 8.

Change Fig. 8 to Fig. 9, and replace the diagram with the attached drawing.

On page 85, under Method, following "The residue shall remain in the retort with the cork and thermometer in position until no vapors are visible; it shall then be weighed," add: "If the residue is to be further tested it shall then be poured directly into the brass collar used in the float test or into a tin box and covered and allowed to cool to air temperature. If the residue becomes so cool that it cannot be poured readily from the retort, it shall be re-heated by holding the bulb of the retort in hot water or steam, and not by the application of flame.

Add the following paragraphs and figures giving description as to float test and coke residue:

Apparatus:

(a) Float or Saucer.—The float or saucer shall be made of aluminum, and shall be of the form and dimensions shown in Fig. 10.

(b) Conical Collar.—The conical collar shall be made of brass, and shall be of the form and dimensions shown in Fig. 11.

Float Test Residue:

Place the brass collar with the small end on the brass plate, which has been previously amalgamated with mercury by first rubbing it with

dilute solution of mercuric chloride or nitrate and then with mercury. Pour the residue to be tested into the collar direct from the retort, as described in part 4 on "Distillation," under Specification for Creosote Oil Analysis: (See page 1265, Vol. 18), or heat it in a tin box on water or steam bath, not by direct application of flame, and then pour into the collar in any convenient way, until slightly more than level with the top. The surplus may be removed after the material has cooled to room

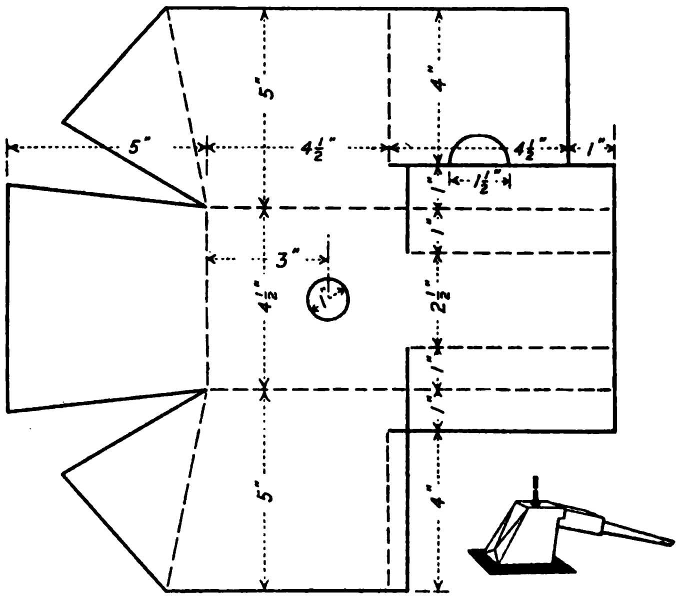


FIG. 9—ASBESTOS SHIELD.

temperature, by means of spatula or steel knife which has been slightly heated. Then place the collar and plate in one of the tin cups containing ice water maintained at 5 degrees Centigrade, and leave in this bath for at least 15 minutes.

Meanwhile, fill the other cup about three-fourths full of water and place on the tripod; heat the water to any desired temperature at which the test is to be made. This temperature should be accurately maintained, and should at no time throughout the entire test be allowed to vary more than 0.5 degrees Centigrade from the temperature specified.

After the material to be tested has been kept in the ice water for at least 15 minutes and not more than 30 minutes, remove the collar with

its contents from the plate and screw into the aluminum float, which is then immediately floated in the warm bath. As the plug of residue becomes warm and fluid, it is forced upward and out of the collar, until the water gains entrance to the saucer and causes it to sink.

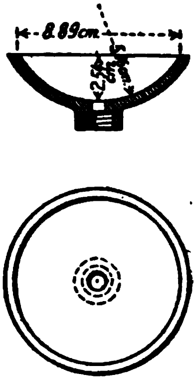


FIG. 10—FLOAT OR SAUCER.

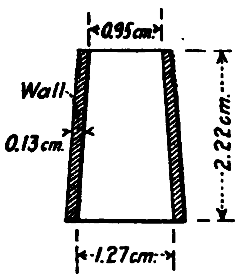


FIG. 11—CONICAL COLLAR.

The time in seconds between placing the apparatus on the water and when the water breaks through the residue shall be determined by means of a stop watch, and shall be taken as a measure of the consistency of the material under examination.

Coke Residue:

Apparatus:

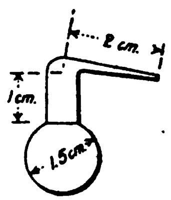


FIG. 12—COKE BULB.

Bulb.—The bulb shall be of hard glass, shown in Fig. 12, and shall have the following approximate dimensions:

Diameter of bulb	15 mm.
Length of vertical neck	10 mm.
Length of horizontal neck	20 mm.
Diameter of orifice	1 mm.

Coke Residue Test:

Warm the bulb slightly to drive off all moisture, cool in a desiccator, and weigh. Again heat the bulb by placing it momentarily in an open Bunsen flame and place the tubular underneath the surface of the oil to be tested and allow the bulb to cool until sufficient oil is sucked in to fill the bulb about two-thirds full.

Any globules of oil sticking to the inside of the tubular should be drawn into the bulb by shaking or expelled by slightly heating it, and the outer surface should be carefully wiped off and the bulb reweighed. This procedure will give about 1 g. of oil.

Cut a strip of thin asbestos paper about ¼ in. wide and about 1 in. long, place it around the neck of the bulb and catch the two free ends close up to the neck with a pair of crucible tongs. The oil should then be distilled off as in making ordinary oil distillation, starting with a very low flame and conducting the distillation as fast as can be maintained without spurting.

When the oil vapors cease to come over, the heat should be increased. The bulb should be held in the highest heat of a Bunsen flame until the evolution of gas ceases, and any carbon sticking to the outside of the tubular is completely burned off. The bulb should then be cooled in a desiccator and weighed and the percentage of coke residue calculated to water-free oil.

Zinc Chloride.

The specification of Zinc Chloride appearing in the 1915 Manual, page 551, is not present practice. It has been revised to conform with present usage, and it is recommended that the following revised specification be inserted in the Manual.

Standard Specification for Zinc Chloride.

The zinc chloride shall be acid-free and shall not contain more than 0.1% iron. Fused or solid zinc chloride shall contain at least 94% soluble zinc chloride. Concentrated solutions shall contain at least 50% soluble zinc chloride.

In presenting this specification, your Committee recommends that it be printed with a separate heading in the new Manual.

Your Committee finds that the practice of using hydrometer readings for controlling the strength of zinc chloride solutions in plant operations is very unsatisfactory, and is of the opinion that a standard method for rapidly and accurately determining the strength of such solutions is very much to be desired. It accordingly recommends for

adoption and insertion in the Manual, the following method for determining the strength of zinc chloride solutions. This method has been in use for many years and combines the factors of simplicity, rapidity and accuracy. It should be clearly understood, however, that this method is recommended only for the control of the solution strengths in plant operation, and not for the technical analysis of zinc chloride as purchased. The latter determinations can be made only by a chemist in a properly equipped laboratory. For such analyses the zinc should be determined directly by any of the well-known gravimetric methods.

Method for Determining the Strength of Zinc Chloride Solution.

Principle.—The chlorine is determined by titration with standard silver nitrate solution and then calculated into zinc chloride according to the following equation:

$$2\ AgNO_3 + ZnCl_2 = 2AgCl + Zn\ (NO_3)_2.$$

Standard Silver Nitrate Solution: 1/10 normal silver nitrate per litre of distilled water.

Indicator: Neutral potassium chromate, $K_2Cr\ O_4$ (Chlorine free), saturated solution, 60 grams in 100 c. c. of distilled water.

Method of Procedure: (a) Specific Gravity.—A quantity of zinc chloride to be tested, sufficient to float the hydrometer, is filtered into a hydrometer cylinder. Filtration is unnecessary if the solution is perfectly clear and free from Creosote Oil. The specific gravity of the filtered solution at 70° Fahrenheit is then determined by means of a hydrometer having a scale reading from 1.000 to 1.060.

(b) Titration.—Two (2) c. c. of the filtered zinc chloride solution are introduced into a 500 c. c. Erlenmeyer flask by means of an accurately calibrated pipette and diluted to about 100 c. c. with distilled water. After adding two (2) drops of the potassium chromate indicator, the solution is titrated with the standard silver nitrate solution, using a 50 c. c. glass-stoppered burette accurately graduated to tenths of a cubic centimeter. The silver nitrate solution is slowly run into the flask until the solution in the flask just begins to assume a permanent reddish tinge, the flask having been gently shaken after each addition of silver nitrate.

(c) Calculation.—The per cent. strength of the zinc chloride solution is calculated according to the following equation:

$$\frac{\text{c. c. } AgNO_3 \times \text{gm. } Ag.NO_3 \text{ per c. c.}}{\text{c. c. } ZnCl_2 \times \text{Sp. Gr. } ZnCl_2} \times 100 \times .401 = \%\ \text{Strength } Cl_2$$

In this equation, the symbols signify the following:

$AgNO_3$=Silver Nitrate; $ZnCl_2$=Zinc Chloride;

$$0.401=\frac{136.31}{2\times 169.96}=\frac{ZnCl_2}{2\ AgNO_3}$$

Grams $AgNO_3$ per c. c.=Strength of the standard silver nitrate solution.

Example: Strength of $AgNO_3$.................. .017 gr. per c. c.
c. c. of $AgNO_3$ used................ 8.2
c. c. of $ZnCl_2$...................... 2.0
Sp. Gr. $ZnCl_2$..................... 1.024

$$\frac{8.2\times .017}{2\times 1.024}\times .401\times 100=2.72\%=ZnCl_2$$

The strength of the standard silver nitrate solution should be approximately 1/10 normal or 16.996 grams $AgNO_3$ per litre. The *exact* strength of the solution must be known and should be indicated on the bottle.*

(d) Precautions.—As the above method is based on the estimation of the chlorine in the zinc chloride, it is essential to determine whether the water used in making up the zinc chloride solutions at the treating plant contains chlorides, and if so to make the proper deductions. Two (2) c. c. of the water should be titrated exactly as described above. The number of c. c. of standard silver nitrate solution required to produce the color change should be noted, and this amount should always be deducted from the number of c. c. of silver nitrate solution required for the titration of the zinc chloride solution sample before making calculations. Where the chlorine content of the water used is found to be variable check determinations should be made.

Use.—This method is for the control of the strength of the zinc chloride solutions as used in actual treatment, and not for the analyses of the fused or concentrated zinc chloride as purchased.

*The standard silver nitrate solution should be made and standardized only by a trained chemist; if the services of such a chemist are not available, the standard solution should be obtained from a reliable chemical supply firm.

Appendix B.

(2) REPORT ON THE COMPILATION OF SERVICE TEST RECORDS AND EXTEND THEM TO INCLUDE TREATED TIMBER IN BRIDGES, DOCKS AND WHARVES.

INCLUDE, ALSO, A CRITICAL STUDY OF THE RECORDS OF SERVICE GIVEN BY THE ZINC CHLORIDE TREATMENT AND STATE DEFINITELY THE RESULTS WHICH MAY BE OBTAINED FROM THAT TREATMENT.

The work on this subject was divided and given to two Sub-Committees. The first Sub-Committee was asked to "Report on the compilation of Service Test Records and extend them to include Treated Timbers in Bridges, Docks and Wharves." The Sub-Committee consisted of E. H. Bowser, Chairman; J. F. Burns, C. F. Ford, C. J. Graff, J. E. Johnson, O. C. Steinmayer and C. H. Teesdale.

The Committee begs to report progress on this work and submits for information this year the work that has been done by the Illinois Central Railroad in generally using Creosoted Water Tanks as their standard. A Creosoted Tank and substructure is shown in Fig. 1. This railroad has erected ten of these tanks to date and is building more.

Mr. C. R. Knowles, Superintendent of Water Service, Illinois Central Railroad, reported to the American Bridge and Building Association as follows concerning these tanks:

The Creosoted Tanks built by the Illinois Central are of their standard sizes, of 100,000 gal. capacity with a 20 ft. stave and 30 ft. bottom, and 50,000 gal. capacity having a 16 ft. stave and a 24 ft. bottom, no change having been made in the plans formerly used for the construction of untreated wood tanks. The timber used is loblolly pine, coming under the general specifications for tank timber, excepting that no restrictions are made as to heart or sap. The timber is air seasoned and should be permitted to season for three months in favorable weather. The method of treatment employed is the Rueping Process, using about 5 lb. of oil per cu. ft. of timber. The oil is a coal tar creosote, coming within American Railway Engineering Specifications, No. 1 Specifications. The tank towers, constructed of 12 in. by 12 in. posts and 6 in. by 8 in. braces, roof, frost box, ladder and all timber entering into the complete structure is creosoted.

A very important feature in the construction of these tanks is that all timber more than 1 in. in thickness is framed before treatment, to secure the maximum life from the treated timber. The work of framing the tank before treatment is given such careful attention that it is rarely necessary even to bore a hole in the treated timber during the field erection of the tank. The work of framing and treating is done by company forces at the Grenada, Mississippi, creosoting plant. The tanks are erected by line gangs. Thus, in the manufacture and erection of these tanks the Illinois Central is independent of outside forces except the mills which cut the timber and ship it to Grenada in the rough.

When one discusses creosoted tanks for the storage of water the question is immediately raised as to the effect of the creosote on the water. In the tank construction on the Illinois Central the presence of creosote in the water has been so slight as to be hardly noticeable and it has had

no detrimental effect whatever upon the water. The Bureau of Industrial Research of the University of Washington conducted extensive tests of creosote wood stave pipe to determine its effect upon water for domestic and irrigation purposes. The test was conducted to determine the effect upon water carried by a 56 in. creosoted wood stave pipe line 22½ miles long from the Lansberg intake on the Cedar River to the Volunteer

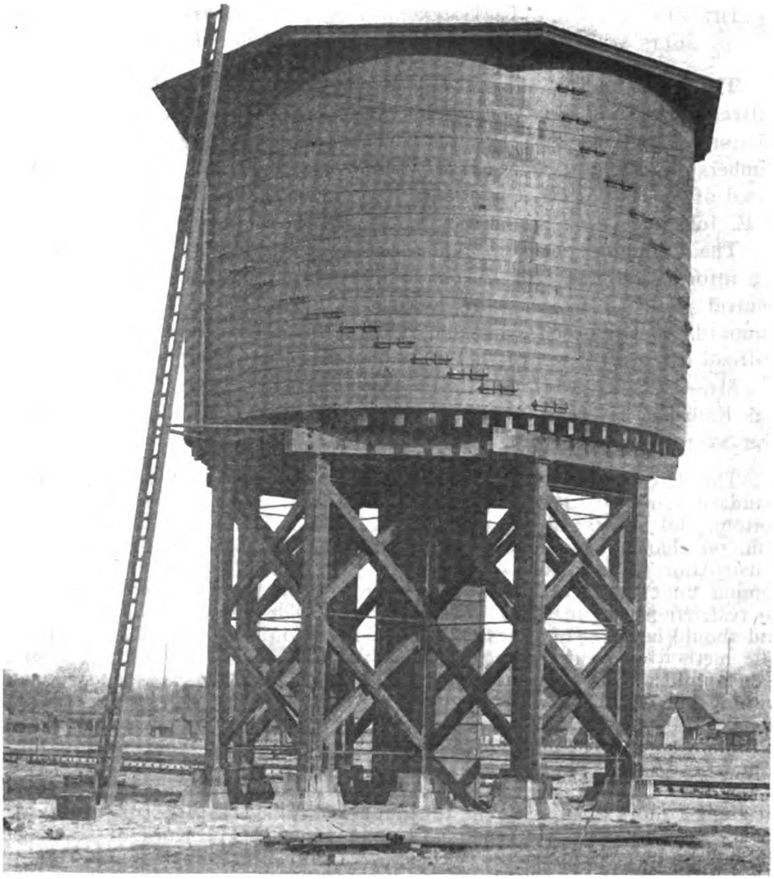


FIG. 1—STANDARD CREOSOTED WATER TANK, ILLINOIS CENTRAL RAILROAD.

Park reservoir in the City of Seattle. In conducting the experiment a smaller pipe was used, but care was exercised to have the conditions in the experiment representative of those existing in the larger pipe lines. The conclusions of the Bureau were that there was no deterimental effect of the creosote on the water. These conclusions were borne out fully by the results on the Illinois Central and the creosoted tank has proven an unqualified success.

Your Committee feels that other railroads could well afford to investigate the matter of creosoting water tanks, as the life of a water tank depends almost entirely on prevention of rot, and if the tank and supports are properly framed and treated a very long life can be reasonably expected.

Zinc Chloride Treatment.

The second Sub-Committee was asked to make "A critical study of the records of service given by the Zinc Chloride treatment and state definitely the results which may be obtained from that treatment. The Sub-Committee consisted of George E. Rex, Chairman; R. H. Howard, Dr. Hermann von Schrenk and J. H. Waterman.

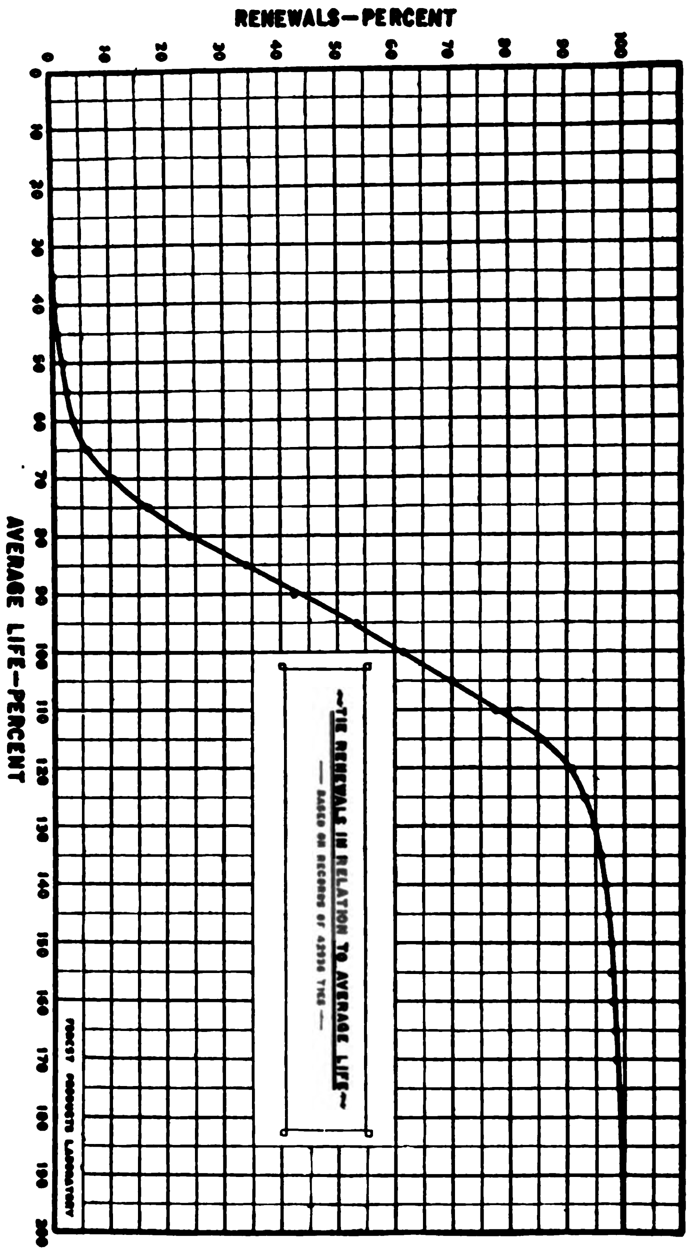
The last general discussion on zinc chloride treated ties was a paper by W. W. Curtis, printed in December number, 1899, of the Transactions of the American Society of Civil Engineers. In this, Mr. Curtis gave a full summary of track experiences in Europe and the United States. Since that time there have been a number of tables and isolated discussions dealing with the general subject of zinc chloride treatment. The question as to what might be expected from treatment with zinc chloride is of very general interest, particularly under the present emergency conditions, and your Committee has, therefore, studied the question.

The supply of creosote oil had been very materially curtailed by the embargo on importation and by the large demands for crude coal-tar as fuel. At the same time there has been the increased demand for creosote oil by the Army, Navy and Shipping Board. In addition, the recognition by the United States Railroad Administration of the necessity for using an increased amount of treated material in railroad operations, has resulted in a demand for much larger quantities of such material than ever before.

In the following report your Committee presents such records as have been found available, together with discussions, and the conclusions drawn from track experience. It has formulated definite recommendations as to methods to be followed in order to obtain the best results with zinc chloride treatment, with general conclusions as to what may be expected of zinc chloride treated ties when treated and used according to these recommendations.

I. Actual Track Records.

Your Committee is indebted to the following railroads for the track records submitted: Chicago, Burlington & Quincy Railroad; Atchison, Topeka & Santa Fe Railroad; Chicago & Eastern Illinois Railroad; Chicago, Milwaukee & St. Paul Railroad; Great Northern Railroad; Union Pacific Railroad; Chicago & Northwestern Railroad and the Wabash Railway. These are actual track records involving in many cases entire divisions as distinguished from experimental sections. Appended to the following records are extracts from comments made by the engineers who transmitted these records. Attention is called to the deductions


RENEWALS—PERCENT
AVERAGE LIFE—PERCENT
TIE RENEWALS IN RELATION TO AVERAGE LIFE

which have been made, in some of the following tables, as to the relationship between the percentage of renewals and average life. These figures are obtained from a curve* developed by the United States Forest Service (see figure).

II. Discussion of Track Records and Factors Influencing Length of Service.

(*a*) *Life Obtained.*—A careful study of the track records and personal conferences with those familiar with the use of zinc treated ties lead to the following conclusions as to the general service which may be expected from ties properly treated with this preservative. Proper treatment will, at least, double the life of an untreated tie in the same situation. To illustrate: If a pine tie would give four years' life untreated, eight years could be figured upon when treated with zinc chloride; and the same result would apply to other woods. To use another example: If an untreated Douglas fir sawed tie, where the rainfall is 25 inches or less, gives six years' life, it may be expected to last twelve years if properly treated and protected from mechanical wear. If this same tie, however, is used in a wet climate, say of 40 inches rainfall or more, it would probably not give over four years' life untreated, but unquestionably would resist decay eight years in the same climate if properly treated.

(*b*) *Influence of the Condition of the Wood Before Treatment.*—The experience of roads which have used zinc chloride treated ties clearly shows that the best results are obtained only when thoroughly sound ties are treated. Undoubtedly, many of the poor results obtained with zinc chloride treated ties were due to the fact that many ties were more or less rotten before they were treated. Figs. 2 and 3 show beech and pine ties which looked perfectly sound on the outside, but, when cut off two inches from the end, showed decay as indicated. Such ties as these, which often are not detected, fail in a very few years. Decayed timber can never be expected to give good service.

It is frequently stated that ties can be properly seasoned along the right-of-way or where cut, and that any deterioration can easily be detected by careful inspection. It has been demonstrated beyond all doubt that visual inspection of ties several months after cutting is not only impractical but frequently very misleading, because of the internal decay not evident on the outside.

The successful preliminary preparation of ties is one of the most vital factors in obtaining successful service, and it is necessary that ties in all stages before treatment be kept in well-ventilated piles, free from every possible kind of infection.

To help prevent these conditions, all ties should be shipped promptly after cutting to the seasoning yard at the treating plant. This means that all yards should be kept free from weeds, decayed wood and standing water.

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*Relation Between Average Life of Ties and Percentage of Renewals, by Mabel E. Thorne (Proceedings 14th meeting, A. W. P. A., page 150, 1918).

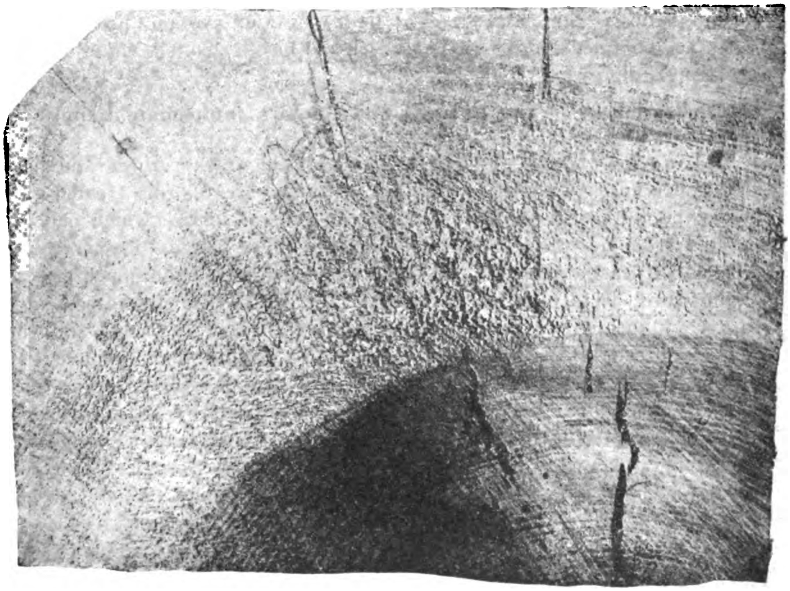


FIG. 2—SAP ROTTEN BEECH TIE APPARENTLY PERFECTLY SOUND FROM OUTSIDE APPEARANCES.

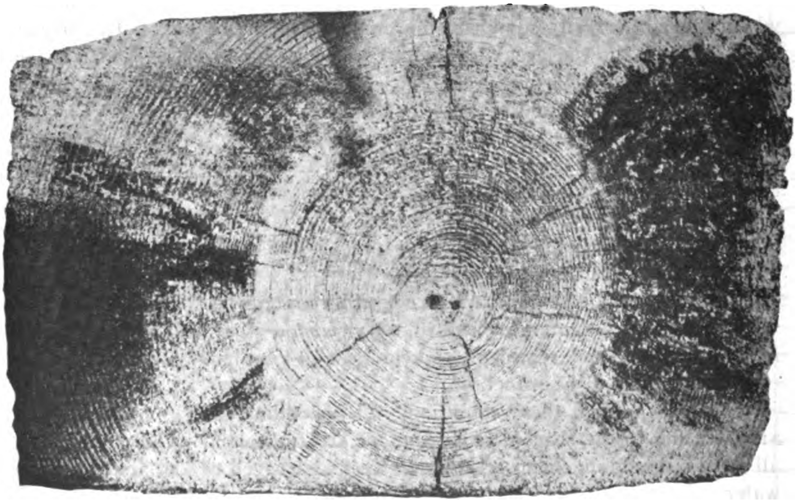


FIG. 3—SAP ROTTEN PINE TIE APPARENTLY PERFECTLY SOUND FROM OUTSIDE APPEARANCES.

The best results from the use of zinc chloride treated ties can only be obtained when the ties are thoroughly air seasoned before treatment. This calls for carefully constructed tie piles, care being taken to keep the stringers as far out towards the ends of the piles as possible and with sufficient air spaces between the piles.

Careful records should be kept of the ages of the tie piles, for it has been found far better to treat ties on the basis of age rather than on visual inspection. The time necessary to properly air season will vary, but in general the best results have been obtained by seasoning red oak ties twelve months and pine ties about four months.

In order to assure proper information as to the age of ties, the Committee finds that some railroads have adopted the admirable system of end-branding the ties as they are taken up by the inspector, with a figure or paint mark, indicating the month of the year in which the ties were cut, which practice we strongly recommend.

(c) *Influence of the Kind of Timber.*—Your Committee finds that the life of zinc chloride treated ties is greatly influenced by geographical factors, conditions of ballast, the amount of traffic, weight of rail, etc. The service obtained is to be ascribed more to these factors than to the kind of timber or the zinc chloride treatment.

In other words, while softwoods like pine have generally given shorter service than hardwoods like oak, this difference is due to the fact that the pine ties rail-cut more rapidly than oak, thereby giving an opportunity for water to lodge under the rail bearings and leach out the zinc salt with the consequent more rapid decay of the pine ties.

(d) *Influence of Climate.*—Climatic influences undoubtedly have a large bearing on the possible length of life. A study of the tables clearly shows that in regions of low rainfall and dry atmospheric conditions, longer life has been obtained than in regions of high rainfall and high humidity. It is also true that the same holds for regions of low mean temperatures as compared with regions of high mean temperatures.

(e) *Influence of Treatment.*—One of the most striking conclusions obtained, from the study made, is that the quality of treatment has the most direct bearing on the ultimate life obtained. It has been clearly demonstrated that poorly treated ties give short service and well-treated ties give longer service. Your Committee finds that poor treatment has been caused by:

1. Excessive steaming of green or partially seasoned ties, in order to obtain any absorption at all. In a great many cases the absorption even after such steam treatment was very poor.

2. The injection of an inadequate amount of zinc chloride.

3. Paying no attention to the relation between the strength of the solution and the duration of pressure, resulting in a large amount of the zinc chloride solution being compacted in the outer layer of wood, when it should have permeated the entire tie.

4. The lack of intelligent and thorough supervision.

(*f*) *Leaching of the Zinc Salt.*—One of the criticisms of the zinc chloride treatment is that the preservative, being soluble in water, leaches out and, therefore, can not be expected to give permanent protection. A general investigation of the results clearly indicates that the leaching process does not take place as rapidly as has been assumed. We have determined from an examination of ties which have been in the track for a number of years that they still retain zinc chloride well distributed throughout the tie. This is more noticeable in drier climates. Your Committee finds that while zinc chloride is a water soluble salt, it leaves the wood very slowly and that sufficient is retained in the wood fiber to give protection that will at least double the life obtained from the untreated wood.

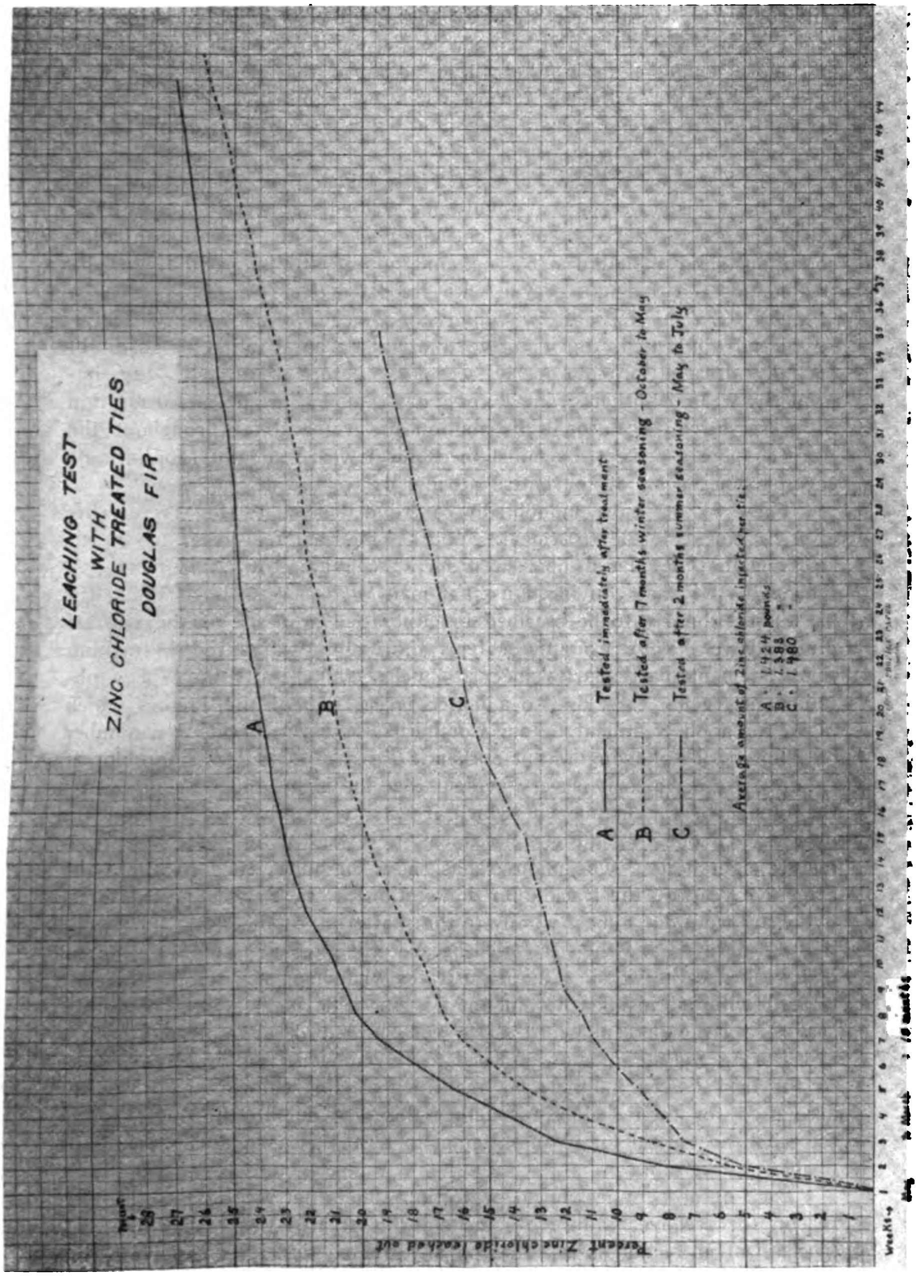
Some years ago a series of leaching tests was made, taking twelve ties for each test. A careful determination was made of the actual amount of zinc chloride absorbed by each individual tie. Some ties were thoroughly air seasoned several months after treatment; others were used freshly treated. These ties were submerged in water for 24 hours and then dried for six days. They were again submerged for 24 hours and dried for six days, this procedure being carried on for several months. After each submersion the actual amount of zinc chloride which had leached out was determined. The results obtained are shown in the accompanying curves, a study of which shows two general results.

Curves A and B show that the loss of preservative from leaching is about the same in the seasoned and freshly treated ties. The small excess of loss from the freshly treated ties is not of any great moment. The more important fact is that while the actual amount which has leached out from the two sets is very nearly the same, yet the manner in which this leaching took place is very different. The solution leached out of the freshly treated ties (Curve A) much more rapidly than from the winter seasoned ties (Curve B). This may be explained as follows:

In the case of the freshly treated ties there was a direct water connection with the preservative in the wood* so that practically all the zinc chloride leached out from the outside of the tie in a very short period of time. With the seasoned tie a very gradual leaching took place from all parts of the tie. This would mean in the case of the freshly treated tie that the outside would very soon be unprotected, permitting decay to start, while in the seasoned tie a more uniform displacement of the salt takes place, insuring longer life.

The summer seasoned ties (Curve C) show a striking difference compared with the other two. The rate of leaching was very much reduced during the same period of soaking and the total amount actually leached out during a given period being very much less than for the other two series. The ties seasoned from October to May, the winter period, dried out very slowly and at the beginning of the test probably

*See "Seasoning of Timber," by H. von Schrenk, Bureau of Forestry, Bulletin 41, Page 12.


LEACHING TEST
WITH
ZINC CHLORIDE TREATED TIES
DOUGLAS FIR
A —— Tested immediately after treatment
B ------ Tested after 7 months winter seasoning - October to May
C —·—· Tested after 2 months summer seasoning - May to July
Average amount of Zinc chloride injected per tie:
A: 1.424 pounds
B: 1.388 "
C: 1.480 "
Percent Zinc chloride leached out
Weeks

still contained considerable water in the wood cells while the ties seasoned from May to July, the summer period, dried out much more rapidly and more completely than the winter seasoned ties. These tests were made under extraordinarily severe conditions, and it is reasonable to assume that if these ties had been in track, the results probably would have been still more striking.

(*g*) *Checking of Zinc Treated Ties.*—One of the results found by actual track inspection is that many zinc treated ties were taken out because of checking. The extent of checking varies with the climate, ballast conditions, and the kind of wood, and appears to be peculiar to zinc treated ties and does not prevail with creosoted ties.

(*h*) *General Reasons for Failure of Zinc Chloride Treated Ties.*—As already indicated, zinc chloride treated ties have failed because (1) partially decayed or improperly seasoning before treatment; (2) improperly treated, either from excessive steaming, insufficient absorption of preservative, or unequal distribution of preservative throughout the tie; (3) poorly protected against mechanical wear; and (4) for lack of careful supervision of the entire process of treatment.

These factors have undoubtedly contributed much to the severe criticism of zinc chloride treatment. Your Committee feels that too much stress cannot be placed upon a proper recognition of these facts. A thorough study has convinced us that many of the records of short life are unquestionably to be ascribed to either one or more of the reasons given above. Your Committee feels thoroughly warranted in making this statement, particularly since so much better results have been obtained in recent years, due to a better recognition of the factors which make for good treatment. Your Committee, however, presents a number of photographs showing recent authentic cases of so-called zinc chloride failures, from which it is very evident that the blame must be placed on the timber or the manner in which it was treated rather than on the process. In one case (Fig. 4) red oak ties were steamed for approximately eight hours. The photographs show the appearance of these ties after five years in the track. On this section of track the renewals after five years were due almost wholly to the shattering of the ties. The wood was not decayed and the ties failed because the excessive steam treatment had weakened the wood. Fig. 5 illustrates what happened when ties were treated with an insufficient amount of zinc chloride. After six years' service a large percentage of these ties showed decay, both under the rail bearing and at the ends, and had to be removed from track. Analyses of the ties showed infinitesimal quantities of zinc chloride, which fully accounted for their failure. Whether this was due to the injection of too small an amount or to the attempt to treat unseasoned ties, we were unable to ascertain.

Lack of proper mechanical protection stands out strongly as another reason for frequent failure of zinc chloride treated ties. While proper mechanical protection is essential on any treated ties, it is especially im-

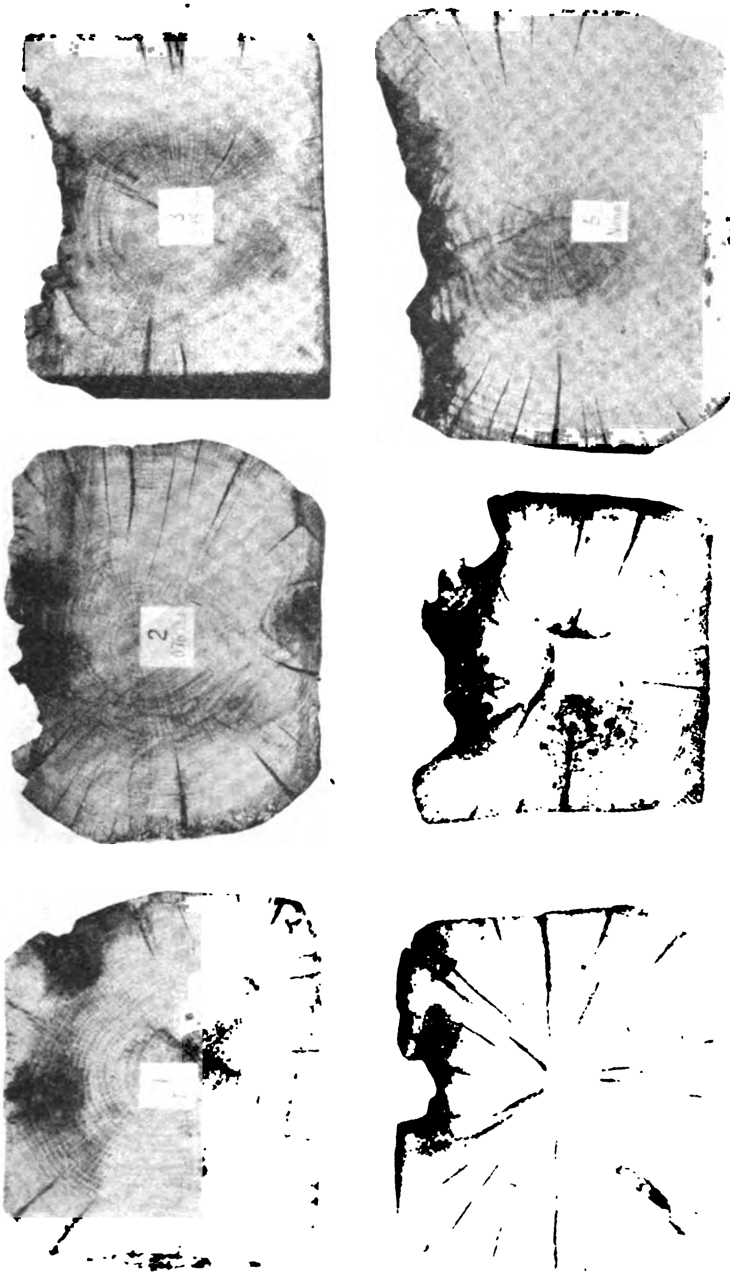


FIG. 4—FAILED RED OAK TIES—DUE TO INSUFFICIENT ZINC OR POOR INJECTION DURING TREATMENT.

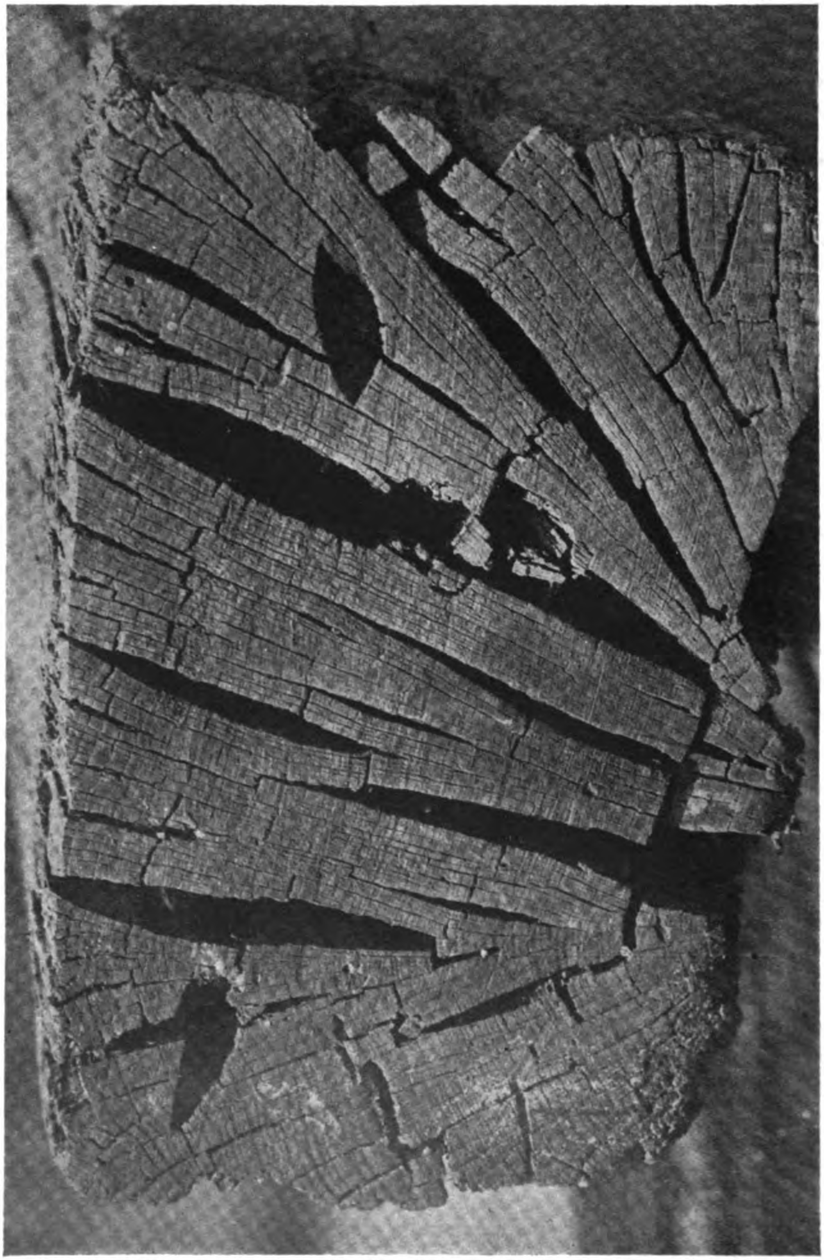


FIG. 5—RED OAK TIES FIVE YEARS IN TRACK—NOTE SHATTERING DUE TO IMPROPER TREATMENT.

portant on those treated with zinc chloride. Very slight mechanical abrasion or injury permits the preservative to leach out of the tie. Hundreds of thousands of zinc chloride treated ties have been removed from track in which the ends and middle were perfectly sound, but which failed immediately under the rail base.

Improper inspection and supervision of treatment is frequently responsible for the failure of zinc chloride treated ties. The solution is colorless and gives in itself no indication of its strength, nor is it easy to determine penetration by borings. Visual inspection of penetration is difficult, and more reliance must be placed on volumetric absorption. Slight errors in determining the strength of the solutions may have serious results. Zinc chloride treatment, furthermore, requires judgment of the condition of the wood before treatment, and a complete appreciation of the many variable factors making for good treatment require technical inspection and supervision at all stages.

III. General Recommendations.

As a result of the study made, we submit the following recommendations with reference to zinc chloride treatment and the use of zinc chloride treated ties. The specification submitted takes the place of the one given in 1915 Manual, page 551, headed Zinc Chloride Treatment.

1. *Handling Ties Before Treatment.*—Ties should be promptly brought to the seasoning yard. All piles should be marked showing the age of the ties, and the fitness of ties for treatment should be based on the number of months seasoned rather than on visual inspection. Under all circumstances there should be absolute assurance that only sound ties are treated.

2. *Treatment.*—All ties should be treated according to the standard specification by the Burnettizing process, as follows:

SPECIFICATIONS FOR THE TREATMENT OF TIES BY BURNETTIZING PROCESS.

Seasoning.—No ties shall be treated unless they are thoroughly air seasoned. The railway's representative shall at all times be the judge as to whether ties are seasoned sufficiently to obtain the required absorption of the preservative.

Classification of Timbers.—Only the same kind of wood, and, as far as possible, only the same sizes shall be treated in the same charge, unless permission is obtained from the railway's representative to treat certain specified kinds of wood or certain specified sizes in the same charge.

Absorption.—The amount of zinc chloride absorbed shall be on the basis of an average of one-half (½) pound of dry zinc chloride per cubic foot of wood. In any one charge the minimum absorption allowed shall be .45 pound per cubic foot. If the average absorption falls below this quantity, the charge will have to be retreated. The maximum ab-

sorption allowed in any one charge shall be .55 pound per cubic foot. Deficiency in absorption in any one charge shall be made up in subsequent charges. Under no circumstances shall the actual solution used be stronger than five (5) per cent. In all cases the solution shall be as weak as possible with the highest possible volumetric absorption.

For red oak ties the solution shall be approximately four (4) per cent., or less, and at least 20 per cent. by volume of the solution shall be injected. For pine and other coniferous woods, the strength of the solution shall be not more than two (2) per cent., and at least forty (40) per cent. by volume of the solution used shall be injected. For woods other than oak and pine the volumetric absorption shall be as high as possible. The exact figure to be used shall be determined by the railway's representative. After determining this figure, the solution to be used shall be as weak as possible, consistent with obtaining an absorption of one-half (½) pound of dry zinc chloride per cubic foot and the necessary volumetric absorption. The amount of solution absorbed shall be determined by calculations based on the gauge readings of the working tanks. The gauge or gauges should frequently be tested as to their accuracy. This absorption should be checked occasionally by weighing an entire charge of ties before and after treatment on a suitable track scale. The weighing of one charge in ten shall be considered sufficient. The strength of the solution at all times and at all stages shall be carefully controlled by chemical titration, using a silver nitrate solution with potassium chromate indicator.

Treatment.—All ties after being placed in the cylinder shall be subject to a preliminary steam treatment for at least one hour and not more than two hours, at a pressure not exceeding 20 pounds. After the steaming, a vacuum shall be drawn for one to two hours, and where it is necessary to break the vacuum in order to empty the cylinder of condensed water, a subsequent vacuum shall be drawn following the emptying of the cylinder. In all cases the most complete vacuum, consistent with the elevation of the treating plant, shall be obtained.

The zinc chloride solution shall then be introduced into the cylinder at a temperature not less than 130° F. nor more than 180° F., and a temperature of at least 150° F. shall be maintained throughout the entire operation. A pressure of approximately 125 or more pounds per square inch shall be applied for a sufficient period to obtain the proper volumetric absorption.

Any ties, regardless of the amount of preservative injected, shall be deemed completely treated when, at any time during the latter part of the pressure period, the pressure having been held at 165 or more pounds continuously for a half-hour period, the absorption during such a period is less than five (5) per cent. of the total volume of zinc chloride solution which is to be injected into the charge.

3. *Handling Subsequent to Treatment.*—Cross-Ties treated with zinc chloride should be air seasoned, preferably at the treating plant after treatment, for at least 60 days before insertion in the track. We base this recommendation on the following factors:

1. Thorough air seasoning of treated ties will give increased strength to cross-breaking and increased spike-holding power. It will also result in reducing plate rail wear.
2. Air seasoned ties will show a saving in shipping weight.
3. By air seasoning ties either at the treating plant or at distributing yards a better distribution will be obtained than if they are scattered on the right-of-way.
4. Air seasoned ties will show a reduced tendency to leaching.
5. It is essential to air season zinc treated ties to prevent signal disturbance.
6. By air seasoning ties at storage yards, a shipping reserve will be established, to be drawn on when cars are available.

4. *Supervision and Inspection.*—All stages of the handling of ties both before and after treatment require careful supervision. It is strongly recommended that provision be made for the thorough supervision of all stages of the treating process by a competent technical man, preferably of chemical training, at the treating plant, under the direction of the railroad official in direct charge of wood preservation.

IV. Where and When Zinc Treated Ties Can Be Used.

The geographic region in which zinc chloride ties could be recommended was made the subject of study by the Committee. Realizing that the present emergency conditions warrant the use of zinc chloride, in many regions where under normal conditions it would not be used, a meeting was called at Madison, Wisconsin, on October 10th, consisting of representatives of the entire timber treating industry, both operating and manufacturing. The purpose of the meeting was to determine the best possible procedure under the emergency conditions, with the result that the following resolutions were unanimously adopted:

1. "That the line of demarcation for the present emergency practice as between zinc chloride and creosote oil in treatment of cross-ties, north and west of which zinc chloride should be used, follow the line of 45-inch rainfall starting on the coast of Texas and going north to the point where the south side of the extended line of the state of Tennessee

would intersect the 45-inch line, follow the south side of Tennessee to the ridge of the Alleghenies, thence following the ridges of the Alleghenies until it intersects the 40-inch rainfall line and thence along the 40-inch line to the Canadian border."

2. "That where due to emergency conditions the supply of creosote oil is not available for ties in region south and east of this line, zinc chloride be used."

Your Committee recommends that these resolutions be submitted to the Association for approval while the present emergency conditions prevail. The basic line upon which the use of zinc chloride treated ties has been drawn was developed from information submitted to the Committee by the United States Forest Service and from information collected by the Committee covering actual track service. It is anticipated that in a subsequent report your Committee will give additional information as to the proper geographic distribution of zinc chloride treated ties, to be followed under normal conditions.

V. General Conclusions:

Your Committee, recognizing that the conclusions to be drawn from track records and track tests may lead to a too optimistic conclusion as to what could be expected on an average over the whole field, and perhaps obscure the possible result to be obtained from other preservatives, while we have faithfully tabulated the service records and other data obtainable, feels that misleading conclusions may be drawn, unless we present the general aspects of the whole situation after the study we have devoted to it, so we, therefore, submit the following conclusions:

1. That creosote is the best timber preserving agent known for all purposes, and by reason that its composition is not affected by either rainfall or temperature, and in addition has a lubricating effect on the wood which diminishes the injury due to mechanical wear, and this combination of qualities places it at the head of all treating preservatives.

2. That where for economic reasons creosote oil is not available, or other conditions of maintenance will not justify the expense for creosote treatment, the adoption of zinc chloride is without question justified in the treatment for ties. Climatic conditions will go further in determining the economy of this treatment than in any other, and as one can unquestionably figure on doubling the life of the untreated timber by its use, and in dry climates this life will undoubtedly be extended.

3. That in localities where the rainfall is excessive and with a humid atmosphere, where good zinc chloride treatment would be unfavorably influenced by leaching, and in any climate where checking of the timber is likely to be excessive, or the mechanical abuse of the fiber is extreme, and it is not considered possible to secure a straight creosote treatment, the introduction of some lubricating agent with zinc chloride will have a beneficial effect in retarding the destruction of the timber from the above causes.

CHICAGO, BURLINGTON & QUINCY RAILROAD, WYOMING DISTRICT. REPORT OF EXPERIMENTAL TIES. ALLIANCE DIVISION.

Location—Near Mystic, S. D., east end of Bridge 73 and laid a little over thirty rail lengths.
Kind of Ballast—Lime Stone and Black Hills dirt.
Tie Plated or Not—Full tie plated.
Weight of Rail—75 lbs.
Rail Changed—Outside rail of curves changed in 1909.
Weight of Rail Originally in Track—75 lbs. laid when ties were laid.
Weight of Rail Now in Track—75 lbs.
Kind of Timber—Red Oak.
Where Treated—Edgemont, S. D.
When Treated—1900.
How Treated—Standard practice at that time, Initial Vacuum, steam from one to three hours, average absorption ½ pound Zinc Chloride per cubic foot.
When Laid in Track—October 1, 1900.
Number Originally Placed in Track—550.
Number Still in Track—350.
When Last Inspected—Oct. 2, 1918, by W. G. Dungan, Supt. Asst., John Cavanaugh, Sec. F., R. C. Pearson, Engr., H. S. Sackett, C. M. & St. P. R. R., and J. H. Waterman.
Remarks—

In 1912 3 were taken out for the laboratory.
In 1913 18 were taken out account decay.
In 1914 50 were taken out account decay.
In 1915 51 were taken out account decay.
In 1916 5 were taken out account decay.
In 1917 35 were taken out account decay.
In 1918 38 were taken out account decay.

Total 200 were taken out to date, or a little over 36%.

Above ties laid on a 3% grade and a 12 degree curve. 100% of them gave twelve years' life, 64% of the ties are still in the track. In other words, 64% have given us 18 years' life. I believe we could get an average of 15 years' service out of Red Oak ties properly treated with Zinc Chloride in Western Nebraska, Colorado, South Dakota and Wyoming. *Untreated* Red Oak ties would not give over 6 years' life, probably 5.

CHICAGO, BURLINGTON & QUINCY RAILROAD, WYOMING DISTRICT. REPORT OF EXPERIMENTAL TIES. STERLING DIVISION.

Location—Mill Posts 41 to 42 between Bridgeport and Alden, Neb.
Kind of Ballast—
Tie Plated or Not—Not tie plated prior to 1913.
Weight of Rail—90 lbs.
Weight of Rail Originally in Track—75 lbs.
Weight of Rail Now in Track—90 lbs.
Rail Changed—1913.
Kind of Timber—Fir Ties.
Where Treated—Sheridan Tie Plant.
When Treated—1900.
How Treated—Standard practice at that time, Initial Vacuum, steam

from one to three hours, average absorption ½ pound Zinc Chloride per cu. ft.
When Laid in Track—1900.
Number Originally Placed in Track—3,200.
Number Still in Track—2,525.
When Last Inspected—Oct. 1, 1918, by J. T. McShane, Supt., J. Toohey, R. M., H. S. Sackett, Timber Engr., C. M. & St. P. R. R., and J. H. Waterman.
Remarks—

490 ties or .153 of these ties taken out up to and including 1916.
7 ties or .002 of these ties taken out in 1917.
178 ties or .056 of these ties taken out in 1918.

Total 675 ties, or a little over 21%.

NOTE: 78.91% have given us 18 years' life. I believe that a Fir Tie, properly treated, in Nebraska, Colorado, South Dakota, Wyoming and Montana will give 15 years' life, providing the rail is 85 pounds or heavier with a good standard tie plate. The mile South of these ties laid with *Untreated* Fir Ties, average life 6 years. Your Committee is very conservative when they say a tie treated with Zinc will double the life of an untreated tie.

CHICAGO, BURLINGTON & QUINCY RAILROAD. REPORT OF EXPERIMENTAL TIES. WYOMING DISTRICT. STERLING DIVISION.

Location—Two miles of track between Sidney, Neb., and Peetz, Colo., M. P. 84 and 86.
Kind of Ballast—Peetz Gravel.
Tie Plated or Not—Tie plated when laid with 90 pound rail.
Weight of Rail—90 lbs.
Weight of Rail Originally in Track—75 lbs.
Weight of Rail Now in Track—90 lbs.
Date Changed—Sept., 1916.
Kind of Timber—Black Hills Pine.
Where Treated—Edgemont, S. D.
When Treated—In 1900.
How Treated—Standard practice at that time, Initial Vacuum, steam from one to three hours, average absorption ½ pound Zinc Chloride per cu. ft.
When Laid in Track—Fall of 1900 and winter of 1901.
Number Originally Placed in Track—6,354.
Number Still in Track—4,968.
When Last Inspected—Oct. 1, 1918, by J. T. McShane, Supt., J. Toohey, R. M., H. S. Sackett, Timber Engineer, C. M. & St. P. R. R., and J. H. Waterman.
Remarks—There were originally laid in this track........6,354 ties

Up to and including 1913 in the two miles............. 285 ties
Taken out account decay:
In 1914 we took out account decay.................... 103 ties
In 1915 we took out account decay.................... 60 ties
In 1916 we took out account decay.................... 75 ties
In 1917 we took out account decay.................... 823 ties
In 1918 we took out account decay.................... 40 ties

Total ties taken out to date...........................1,386 ties
Total percentage 21.81 taken out to date.

NOTE.—78.19 per cent. of these ties have already given us 18 years' service, which indicates that in Western Nebraska, Colorado, South Dakota and Wyoming ties properly treated with Zinc will give good service. I do not hesitate to make the statement that we ought to get an average of 15 years' life out of this class of ties properly treated, providing the rail was 85-lb. or heavier, using a good heavy tie plate. *Untreated* Black Hills Pine will not give us over 5 years' life.

THE ATCHISON, TOPEKA & SANTA FE RAILROAD COMPANY.

Hewn and Sawed Pine ties inserted near Newton, Kansas, between M. P. 179/264 and 184/3036, treated with chloride of zinc and inserted in 1904 and 1905; treatment as follows:

Air seasoned, Initial vacuum, 24 inches; 45 minutes; 20 lbs. steam, three hours, 30 minutes; pressure 100 lbs., two hours; temperature 200 degrees Fahrenheit; absorption, Hewn ties, .58; Sawed ties, .52.

			Taken Out					
Kind of Tie.	Inserted.	Number.	1915.	1916.	1917.	1918.	Total.	Still in Track.
Hewn Pine......	1904	6,357	2,257	219	540	1,904	4,920	1,437
Hewn Pine......	1905	9,251	3,047	572	434	190	4,243	5,008
Sawed Pine.....	1904	2,517	1,054	349	86	175	1,664	853
Sawed Pine.....	1905	40	....	16	6	13	35	5

Hewn Pine, 1904; 14 years in track. Percentage, 22.59.
Hewn Pine, 1905; 13 years in track. Percentage, 54.13.
Sawed Pine, 1904; 14 years in track. Percentage, 33.89.
Sawed Pine, 1905; 13 years in track. Percentage, 12.50.

The above tests when applied to the table as suggested by the Forestry Products Laboratory (see Railway Review, January 26, 1918, page 133), showing the relation between average life and percentage renewals, would indicate an average life of 14 years for these ties in a rainfall area of 30 inches.

At least three years of this unusual average life can be credited to the fact that they were laid out of face and were thoroughly air seasoned after treatment before the traffic was put on them.

CHICAGO & EASTERN ILLINOIS RAILROAD.

RESULTS OBTAINED FROM ZINC TREATED TIES ON ILLINOIS DIVISION AS OF JANUARY 1, 1918.

		Removed from Track								
Ties Inserted, Year.	Renewals.	1911.	1912.	1913.	1914.	1915.	1916.	1917.	Total.	Per Cent. Removed.
1906	106,122	364	94	77	3,737	6,039	10,225	7,115	27,681	26.08
1907	79,963	...	68	34	1,752	1,874	2,366	3,513	9,607	9.05
1908	17,547	...	...	249	77	148	539	701	1,714	9.76
1909	869	...	...	...	321	9	49	7	386	44.41
1910	5,085	...	...	...	....	....	....	38	38	.74

The above tests when applied to the table as suggested by the Forestry Products Laboratory (see Railway Review, January 26, 1918, page 133), showing the relation between average life and percentage renewals, would indicate that when applied to the 1906 ties in the above test, an average life of 13.6 years.

CHICAGO, MILWAUKEE & ST. PAUL RAILROAD COMPANY.

300 Burnettized Red Oak Ties, Laid at McLaughlin, S. D., in a Semi-Arid Region.

Year.	Inserted.	Taken Out 1913.	1914.	1915.	1916.	1917.	Total Removed.	Per Cent. Re-moved.
1906	300	1	13	0	0	43	47	15.7

500 Sap Pine Burnettized Ties, Laid at Morristown, S. D., in a Semi-Arid Region.

Year.	Inserted.	Taken Out 1913.	1914.	1915.	1916.	1917.	Total Removed.	Per Cent. Re-moved.
1906	500	0	0	10	0	43	53	10.6

500 Sap Pine Burnettized Ties, Laid at Washington, Iowa. Rainfall Between 30 and 35 Inches.

Year.	Inserted.	Taken Out 1913.		Total Removed.	Per Cent. Re-moved.
1903	500	31	104 removed between 1913 and 1917	135	27.0

GREAT NORTHERN RAILWAY COMPANY.

Office of Engineer, Maintenance of Way.

Summary of Tie Renewals.

Tie Life Record Miles—Various Divisions.

Treated Ties.

Division.	Line.	Number Ties Originally Placed.	Years in Service.	Renewals Num-bers.	Renewals Per Cent.
Minot	Granville	2,848	14	934	33
Minot	Granville	2,580	14	655	25
Butte	Shelby	2,601	15	2,239	86
Butte	Billings	2,562	10	39	1
Kalispell	Main	2,823	13	2,501	88
Kalispell	Main	2,708	13	2,254	83
Spokane	Main	2,918	14	2,918	100
Totals (7 miles)		19,039		11,590	
Average (1 mile)		2,720	13.3	1,656	60

Untreated Ties.

Division.	Line.	Number Ties Originally Placed.	Years in Service.	Renewals Num-bers.	Renewals Per Cent.
Minot	Granville	2,824	13	1,706	60
Minot	Granville	2,540	13	1,810	71
Butte	Billings	2,989	9	1,696	57
Butte	Billings	2,916	9	2,445	83
Kalispell	Main	2,165	10	2,168	100
Spokane	Main	2,894	9	2,872	99
Totals (6 miles)		16,331		12,697	
Average (1 mile)		2,722	10.7	2,116	77.7

1-16-18 (to season 1917, inclusive.)

EXTRACT FROM LETTERS FROM RALPH BUDD, AUGUST 17TH AND 21ST, 1918.

"These figures show in a general way the life of the treated tie to be approximately double that of the untreated tie.

"It will be noted the several stretches of track located on parts of our line subjected to an annual rainfall, ranging between 12 inches and 25 inches.

"I can say positively that the results have been highly satisfactory, and that in the section of the country where we use Zinc Chloride, namely, east of the Cascade Mountains, on account of the moderate rainfall, we believe the Zinc Chloride treatment fully justified, even in normal times when creosote can be obtained."

UNION PACIFIC RAILROAD.

While the Union Pacific does not present any specific test, we quote from Mr. Huntley's letter of September 17, 1918, what we consider very interesting and instructive information:

"Treatment of Wyoming Pine Ties by the Zinc Chloride Process was commenced in January, 1903, and during the period January, 1903, to July, 1905, specifications called for the use of .4 of a pound of zinc chloride to the cubic foot of timber or 1.4 pounds to the tie, based on 3.5 cubic feet to the tie. From July, 1905, to February, 1913, this was changed and specifications called for the use of ¼ pound of zinc chloride to the cubic foot of timber, or .875 of a pound to the tie, based on 3.5 cubic feet to the tie.

"Present specifications call for the use of .4 of a pound of zinc chloride to the cubic foot of timber.

"As shown by monthly report of Wyoming Pine treated ties removed from tracks by divisions, a great many of the ties placed in tracks in 1903, 1904 and 1905 show 11 and 12 years' and in some cases 13 years' service, while quite a number of ties treated during the period of July, 1905 to 1913, when specifications called for the use of ¼ of a pound of zinc chloride to the cubic foot of timber, show the average life as seven, eight and nine years."

CHICAGO & NORTHWESTERN RAILWAY.

QUOTATIONS FROM LETTER FROM G. M. DAVISON, AUGUST 24, 1918.

"Have no definite tests to submit, but we are satisfied that ties treated with a half-pound per cubic foot of chloride of zinc have twice the life of untreated ties.

"In regard to the practice of seasoning after treatment; we try to season these ties sixty days or more, but, under conditions that exist this year, they are not stored or seasoned."

WABASH RAILWAY COMPANY.

Statement of Zinc Treated Ties Furnished to the Wabash Railway per Their Record, and Total Treated Ties Marked with Dating Nails in Track, January 1, 1918.

Eastern Division.

(Detroit to Peru.)

Year.	Inserted.	In Track Jan., 1918.	Per Cent. Removed.	Average Life.	
1903	31,398	23,158	71.55	12.5 years	Follows approximately the line of 35" rainfall.
1904	324,171	111,332	65.66	12.4 "	
1905	91,211	35,098	61.52	11.75 "	

Middle Division.

(Decatur to Springfield.)

Year.	Inserted.	In Track Jan., 1918.	Per Cent. Removed.	Average Life.	
1903	146,047	10,218	93.69	11 years	Follows approximately the line between 35" and 40" rainfall.
1904	322,715	23,351	92.76	10.2 "	
1905	228,006	24,089	89.44	9.8 "	

The above tests when applied to the table as suggested by the Forest Products Laboratory (see Railway Review, January 26, 1918, page 133), showing the relation between average life and percentage renewals, would indicate an average life as shown above.

Appendix C.

(5) REPORT ON INDICATORS FOR DETERMINING THE BURNETTIZING OF TIES AND TIMBERS.

Your Committee begs to report that considerable work has been done on this matter during the year. The Sub-Committee in charge was F. J. Angier, Chairman; Dr. Hermann von Schrenk, Geo. E. Rex and O. C. Steinmayer.

The basis for the investigation was the work done by E. Bateman, Chemist on Forest Products, and his report issued by the United States Department of Agriculture, Forest Service, Circular 190, entitled "A Visual Method for Determining the Penetration of Inorganic Salts in Treated Wood."

In his method a representative disk of the treated wood is cut as a test piece. The freshly cut surface is dipped for an instant in a 1 per cent. potassium ferrocyanide solution. The entire surface should be moistened, but the disk should remain in the solution not more than 10 seconds. After the disk has been thus moistened, the excess of the solution is removed from the face by blotting paper. The moistened block is then dipped into a 1 per cent. solution of uranium acetate and allowed to dry. At first the whole block may have a reddish tinge, but, on drying, the untreated portions will have a dark red or maroon color, while the treated portions will be slightly whiter than the natural wood."

"On account of the color of the uranium ferrocyanide the test cannot be used on red oak, because the natural color of the wood masks that of the uranium compound."

Mr. Bateman, in order to determine the accuracy and reliability of this method, analyzed borings taken at various depths from the surface of a sap tie and found that this method "is capable of detecting the presence of zinc chloride in treated wood when present in amounts as small as 0.17 pound of salt per cubic foot of wood, or rounding off the second decimal, 0.2 pound per cubic foot."

While this method has been in use for several years, many operators have found that the method of applying the test was not satisfactory, and also that the line of demarcation between the treated and untreated areas was not clear and distinct.

Your Committee has developed the following method, which continues to use the same chemicals as given by Bateman.

The apparatus required is an ordinary atomizer (see Fig. 6). Stock solutions of uranium acetate containing 5.64 grams dissolved in 250 cubic centimeters of distilled water and of potassium ferrocyanide containing 2.44 grams dissolved in 250 cubic centimeters of distilled water are the two chemical solutions required. Fifteen cubic centimeters each of these stock solutions are mixed together in the atomizer before making the tests. The mixture oxidizes when left standing for more than a day and,

therefore, the two chemicals must be kept in separate bottles until they are mixed for using.

The disk of wood is completely sprayed with the mixture by means of the atomizer until the whole surface of the disk shows a reddish-brown coloration. The disk is then allowed to dry either in a warm room or in a drying oven. After this drying period, a faint line of demarcation is apparent between the treated and untreated areas. A second application of the mixture is then made over the area of demarcation. This application, upon being allowed to dry, brings out very distinctly the demarcation line and shows the depth of penetration of the preservative.

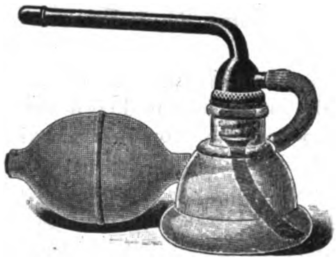


FIG. 6—ACORN ATOMIZER.

If a very distinct line is required for photographic purposes, repeated applications with the mixture and drying between applications will give a still more distinct line.

Your Committee feels that these changes in the application of Mr. Bateman's method is a very decided improvement and should be used by all operators in checking the penetration of the preservative in the Burnettizing process.

The Committee is working on a method for determining the penetration of Zinc Chloride in Red Oak and hopes to have this ready for next year.

REPORT OF COMMITTEE XIV—ON YARDS AND TERMINALS.

B. H. MANN, *Chairman;*
MAJOR W. G. ARN,
HADLEY BALDWIN,
MILES BRONSON,
G. H. BURGESS,
A. E. CLIFT,
L. G. CURTIS,
H. T. DOUGLAS, JR.,
MAJOR A. C. EVERHAM,
E. M. HASTINGS,
REUBEN HAYES,
D. B. JOHNSTON,
A. MONTZHEIMER, *Vice-Chairman;*
LIEUT.-COL. F. E. LAMPHERE,
H. J. PFEIFER,
S. S. ROBERTS,
C. H. SPENCER,
E. B. TEMPLE,
E. E. R. TRATMAN,
E. P. WEATHERLY,
W. L. WEBB,
A. J. WHARF,
J. G. WISHART,
Committee.

To the American Railway Engineering Association:

The Committee on Yards and Terminals submits herewith its Twentieth Annual Report:

The subjects assigned to the Committee by the Board of Direction for consideration are as follows:

1. Make critical study of the subject-matter in the Manual, and submit definite recommendations for changes.
2. Report on Unit Operation of Railroad Terminals in Large Cities.
3. Report on handling of freight in double-deck freight houses and cost of operation. Also report on handling of freight by mechanical means.
4. Continue study of typical situation plans for passenger stations and methods of their operation.
5. Report on classification yards, including methods of switching from classification yards to advance yards.
6. Report on advantages of a small sorting yard with grade sufficient for gravity switching to be located between classification and advance pocket, for the purpose of switching trains into station order.

The Roll of Honor of the Association includes the following members of your Committee:

MAJOR W. G. ARN,
MAJOR A. C. EVERHAM,
LIEUT.-COL. F. E. LAMPHERE.

At a representative meeting of the Committee called to plan the season's work and held in the rooms of the Association at Chicago on June 18, 1918, it was the feeling of the members that, on account of the war conditions and because of the Federal operation of railroads, Subject No. 2, "Unit Operation of Railroad Terminals in Large Cities," was one of such importance that it could well engross the best efforts and

thought of the Committee. It was agreed that each member of the Committee should familiarize himself with the work, methods and information obtained by the local unification committees in his vicinity, and from this and his own experience be prepared to unite in proposing a complete, logical and practical general method for the proper unification of terminals, as useful as the Committee's Catechism of last year on "War Emergency Yard Improvements."

The Committee believed that there was no other work which its members might do which would be of more benefit both to the general railroad situation and to the members' individual road than this.

It was agreed that, as the congestion in traffic movement had extended over a somewhat greater time in the Eastern territory, there would be a greater opportunity for study of relief measures near some Eastern Terminal.

There was almost unanimous approval and encouragement by the Regional Directors of the proposed plan of handling this feature of the Association's current year's work so that the Committee was permitted to and did comply wholeheartedly with the suggestion of the Regional Director that a meeting be held in Philadelphia. This meeting was held August 27th to September 1st, inclusive, in Philadelphia and Atlantic City, and during the morning, afternoon and evening sessions, which were held to the number of fifteen, there were present thirteen members of the Committee, and as guests: Messrs. G. D. Brooke, Allegheny Region, U. S. R. A.; E. H. Lee, Chicago & Western Indiana Railroad Company; F. E. Morrow, Chicago & Western Indiana Railroad; J. J. Snavely, New York, New Haven & Hartford Railroad.

At the close of this meeting the preliminary report upon Subject No. 2 was forwarded to the Secretary and was immediately issued as advance information in a Bulletin of the Association, Volume 20, No. 208. It has since been widely distributed by each Regional Director.

The individual after-experiences of the members of the Committee lead them to believe that one result of this distribution of the preliminary report by the Regional Directors among outside officials has been the creation of an interest in the Association in the minds of a number of railroad Transportation and Operating officials not now members, which should be later, if fostered, of mutual benefit to your Association and themselves.

A third general meeting of the Committee was held at the office of the Secretary of the Association in Chicago on November 18th and 19th, at which there was a good attendance of members of the Committee, and, by invitation, Mr. F. E. Morrow, Chief Engineer, Chicago & Western Indiana Railroad.

For the final report of the year it was voted:

SUBJECT No. 1.

That Committee recommend no change in the current subject-matter in the Manual.

Subject No. 2.

Unit Operation of Railroad Terminals in Large Cities

Definition.—Unit Operation of Railroad Terminals contemplates such modified control and use of individual organizations and properties including physical changes therein as will serve the transportation purposes of the terminal district, considered as a unit, with the greatest expedition and economy.

President Wilson has repeatedly emphasized the necessity of conservation of men and materials as the means of winning the war and he and others have shown, without peradventure, that the concerted, patriotic efforts of those men at home, engaged in essential employment directed in intelligently organized teamwork, are the means of successfully maintaining our soldiers on the front line. Therefore the self-sacrificing, unselfish and untiring endeavor of every man is demanded, regardless of rank or station, as a duty which is as evident and as exacting as that of the man in uniform.

There is no other single industry or calling which so directly and vitally affects the maintenance of our armies as that of Transportation, and it is the cherished purpose of every railroad man to give the best that in him lies, and it shall be his pride, after victory, to be able to point to the vast army of railroad men and say that in this whole multitude there was no slacker. This may be realized only provided no man shirks a duty which imposes increased labor, responsibility, or the doing of a little more or the doing of a thing a little differently from the manner in which he has agreed to perform it or has performed it in the past.

This is the time of an emergency, and the Bible itself tells us that it is not only proper but our duty to set aside its command if our ox is in the ditch, and to get him out. Therefore, any human contract, principle or ideal which conflicts with or would obstruct the endeavor to get the most out of the means we have for serving our Government in conservation of men and materials must yield for the time being, in whole or in part, to the greater obligation.

The railroads of the country have been likened to a broad, deep canal, ample to bear all commerce which it may be desired to carry upon its surface; and the terminals, to locks, which possibly are neither so wide nor so deep, and whose operation requires time, so that the capacity of the system is limited by the capacity of the locks.

It is necessary then, in order to make congestion as slight as possible, to concentrate endeavor upon the locks—the terminals.

It is evident that if the terminals are kept open, the whole system may be kept in motion.

Congestions are malignant infections, which first appear in the terminals and spread to the tributary lines and even to other terminals, though the cause may often originate outside of them.

To keep open the terminals and to prevent or to cure congestions, the best advantage must be taken of every facility within the terminals and remedy must be applied to the causes beyond the terminals which make or contribute to the trouble.

The aggravating causes outside of the terminals may be lessened by routing around the terminal and by the refusal of shipments at the points of origin in times of threatened congestion. That is, the trouble should be attacked as near the source as possible.

The most effective cure within the terminal is the adoption of good methods and practices of operation in a system of terminal facilities constructed or reconstructed upon a comprehensive plan developed to best fulfill the requirements of each particular situation.

In the present emergency, time is of essence, and extensive physical changes are generally neither advisable nor practicable. Therefore the most immediate relief must be sought in the improvement of operating methods and practices which may be put into effect at once, accompanied by such physical changes as may be made quickly and are imperatively necessary to effect savings in operation by making available the unification of the existing physical plant.

At some cities or terminals, while pronounced benefits and advantages may be secured by pooling or unifying existing facilities, etc., it may be that the situation demands such relief as can be made effective only by large capital expenditures and the obliteration of exclusive interests, attended by extensive retirements, modifications and additions of facilities.

In such a case, where it can be foreseen that a plan of this kind would prove justifiably and permanently advantageous to the movement of traffic, the solution would seem to be the surrender of individual properties and the merger into a terminal company or association of all facilities in the terminal zone.

It is the earnest thought that each situation should be thoroughly studied, and a comprehensive plan developed for each, before any extensive physical change be undertaken, and that either small or important changes which are made should be in line of development of the ideal plan.

As has been said, the application and distribution of man-power to achieve those methods and practices in operation that will give the nearest approach to the ideal plan is the most immediately available fruitful source of relief.

Fundamental Principles of Unification of Terminals

Underlying the unification of terminals are the following fundamental principles:

(1) A terminal is a clearing point and not a storage point for cars.

(2) Each and every facility within the unified terminal limits must be considered absolutely a part of the whole plant. The word "facility," as used, includes "man-power."

(3) The use of each individual part must be coördinated so as to obtain the best use of the plant as a whole.

(4) Each individual operating organization must be coördinated and directed under one head.

The full application of these principles should give the most economical operation of the plant:

By accomplishing the most expeditious and efficient movement of cars;

By avoiding duplications of service, as switching, clerical and other work, and of facilities; and

By employing man-power as well as physical facilities and mechanical power to capacity, where and when necessary.

As prerequisite to terminal unification, the following information, or its equivalent, should be obtained and analyzed:

(1) A situation or key map on a small scale showing or indicating:

- **(a) The entering lines;**
- **(b) The terminal facilities of each line;**
- **(c) The interchange connections and junction points of the lines in the district to be unified;**
- **(d) The location and capacity of yards; engine terminals, including coaling and water stations, cinder pits, sand-houses and engine parking tracks; freight houses, transfer platforms and team-tracks;**
- **(e) The location and track capacity of large industries and private warehouses.**

(2) Larger scale maps, indicating the facilities of each road, in sufficient detail, for critical study.

(3) Topographical maps of the territory, where necessary.

(4) Record of traffic handled by each line, divided:
   (a) As to local or through, as referred to the district;
   (b) As to prevailing and possible routing; and
   (c) As to preponderance of direction of tonnage due to commodities and seasons.

(5) Outline of present method of operation, considering:
   (a) General movement;
   (b) Transfer or interchange movement;
   (c) Use of individual facilities, yards, engine facilities, freight houses, etc.

(6) It is the thought that the investigation of and recommendation for any terminal unification should be made by a representative committee composed of representatives of all departments—transportation, engineering, mechanical and traffic officials, including, where complex situations are involved, at least two members from other locations than the terminal under study, and in every case officials responsible for operating the consolidated terminal.

(7) The officials should be clothed with authority and instructed to make the recommended unifications effective within or by definite dates.

Catechism on Unit Operation of Railroad Terminals

In the operation of the unified terminal facilities, the load should be distributed evenly among all units so as to secure their constant normal use at the most intense efficient rate, coupled with avoidance of any excess peak load on any unit, treating both the individual carrier's terminal and the unified terminal always as a part of the railroads as a whole.

Certain captions under which improved conditions may be obtained by unification have been selected and, while constantly bearing in mind the fundamental principles first enumerated, questions are asked under each caption which will suggest changes that will be fruitful of good results in any unification where local conditions are favorable.

QUESTIONS.

Interchange.

(1) Are you now handling maximum number of cars by the most economical or direct route, either existing or reasonably attainable?

(2) Can the number of interchange movements be reduced advantageously by combining movements from various origins to various destinations?

(3) Can you extend the practice of reciprocal interchange now working so advantageously at many points?

(4) Are you interchanging directly between yards instead of on assigned interchange tracks? Could not delay and rehandling be reduced by so doing?

(5) Are you, as far as practicable, making interchange with regular crews who are familiar with the routes and the work to be done?

(6) Can volume of direct interchange be increased by minor track changes or changes in practice?

(7) Are interchange facilities at any point inadequate for periods of heavy traffic under new conditions, and, if so, is it practicable at reasonable cost to make necessary increase of capacity, or is it better by rerouting interchange to relieve the situation?

(8) Have you any separate route of interchange that could be discontinued to advantage by consolidation with another route?

(9) Can you have cars grouped, either in cuts or solid trains, before they reach the terminal, so as to reduce terminal switching?

(10) Can interchange in any terminal be reduced to advantage by rerouting through outside junctions?

<u>Consolidation of Industry and Team-Track Switching.</u>

(11) Have all industrial plants sufficient track capacity and other facilities so that cars may be promptly placed, loaded or unloaded to the full capacity of the plant during each working shift without unduly frequent switching or interference with plant operation?

(12) Can you arrange for "one line" switching of individual or grouped industries or team-tracks?

<u>Consolidation of Yards.</u>

(13) Can greater efficiency in yard operation be obtained through the consolidation of the yards of one or more railroads:

(a) By dividing large terminals into zones and assigning as great a number of receiving yards to as small a number of classifying yards as possible, thereby assembling the maximum number of cars into the minimum number of classifications?

(b) By pooling similar yards of neighboring railroads so as to conserve yard room, avoiding both the duplication of switching and interchange between yards?

(c) By consolidating existing facilities, adapting such combined facilities to a new program of operations which disregards prior uses, with or without minor physical changes; or by pooling the same in the sense that one line's facilities are used to serve the overflow of traffic confronting a neighboring line's facilities?

(d) By combining the use of two or more yards to adapt them to the segregation of freight with respect to commodities or destinations?

Consolidation of Engine Terminal Facilities.

(14) Can you re-assign or coördinate the use of engine terminal facilities so as to avoid or reduce delay and congestion, reduce expense and engine miles, or improve supervision?

(15) To what extent can neighboring engine terminal facilities be adapted to the economical housing and handling of engines grouped according to the nature or location of their service or their size without regard to road ownership?

Consolidation of Car Inspection.

(16) Has "single inspection" been instituted wherever cars are interchanged?

(17) Can greater efficiency be obtained by consolidating the car inspection forces at adjacent yards, junctions or stations?

(18) Are car inspections and repairs so made as to insure safety and prevent further damage to equipment and lading?

(19) Is such inspection made so as fully to detect violations of loading rules and are these rules effectively enforced in every case of such violation?

(20) Has the force of inspectors been EDUCATED to the making of effective inspection and is the inspection followed unremittingly by the making of adequate repairs?

Consolidation of Car-Repair Work.

(21) Can you obtain greater efficiency through extending consolidation of car repair forces and facilities:

(a) By combining in one repair yard the work of one or more roads?

(b) By combining the forces and facilities in a given zone?

(22) Do you require car inspectors at outlying points to repair cars as far as possible and to make light repairs to cars in industrial districts where cars are "made empty" or placed empty for loading?

(23) Are you keeping maximum number of cars in service by giving preferred attention to those needing light repairs?

Consolidation of Car Records.

(24) Can the number of records and incidentally the amount of clerical work be reduced:

(a) By the consolidation of car record departments?

(b) By the consolidation of car record forces, in yards reasonably near, one to the other, whether these yards are combined or not?

(c) By the elimination of certain intermediate car records on each road through a more comprehensive and manifold use of train and yard reports so as to supply the greatest amount of information from each report?

Consolidation of Freight House Facilities.

(25) Can the freight houses of two or more lines be so combined that certain houses may be used for inbound and others for outbound business?

(26) Can the use of a freight house be discontinued transferring its business to another, or to a combination of other freight houses?

(27) Can certain freight houses be assigned to designated commodities (perishable or non-perishable)?

Transfer of Freight Between Freight Houses.

(28) Are you preventing transfer of freight between freight houses:

(a) By loading more intelligently at originating points?

(b) By utilizing more fully in both directions drays, tractors, trucks, tunnels, or other means of conveyance, so as to reduce the use of trap cars and save rehandling?

Consolidation of L.C.L. Business at Terminals.

(29) Are you coördinating:

(a) The routing of L.C.L. freight;

(b) The use of freight houses at either end of the route;

(c) The use of transfer stations;

to avoid:

(1) Congestion;

(2) Unnecessary local transfer of freight between houses;

(3) Light loading of cars?

(30) Have you adopted "Sailing Days" for L.C.L. freight:

(a) To secure better and heavier loading of cars?

(b) To avoid breaking bulk in transit?

(c) To reduce loss and damage in transit?

(d) To avoid "overs and shorts" by such stowing in the car as to make individual shipments readily accessible in "peddler" cars at intermediate stations?

(31) What may be done in the way of extending railroad service to include "store door delivery" of freight?

Consolidation of Team-Tracks.

(32) Can team-tracks in reasonably adjacent territory be consolidated and thus bring about:

(a) Reduction in classification?

(b) More intensive use of valuable terminal property?

(c) More prompt release of cars?

(d) Greater convenience to the public?

(e) Avoidance of a needless duplication of operation or maintenance?

(f) The use of yards near passenger stations for baggage, mail and express when desirable?

Bureau of Collection of Freight Charges.

(33) Where collection of freight charges is necessary at other than stations, have you given consideration to:

(a) Collection for all railroads by zones as a matter of economy and public convenience?

(b) Collection for all railroads from all sources by a designated bureau?

Consolidation of Wharves, Docks and Elevators.

(34) Can you obtain greater efficiency in the use of waterfront facilities of one or more railroads by consolidation of:

(a) Coal piers;

(b) Grain elevators;

(c) Merchandise piers;

(d) Other piers;

so as to:

(1) Reduce number of units operated;

(2) Take full advantage of most modern facilities to reduce double handling of freight;

(3) Release facilities for other uses;

(4) Reduce switching or floatage;

(5) Secure more prompt release of cars?

(35) Will beneficial results follow the placing of all waterfront facilities, or those in certain zones, under single control?

Consolidation of Passenger Station Facilities.

(36) Can you obtain greater efficiency in operation through extending consolidation of the passenger facilities of one or more railroads:

(a) By combining forces of two or more lines using the same station?

(b) By using one or more stations for handling the business of two or more lines, thus enabling certain stations to be closed?

(c) By coördinating the use of stations so as to handle in the same station the traffic from or to certain regions?

(d) By continuing the use of adjacent stations, but consolidating their forces?

(e) By abandoning passenger service on certain sections of a line, the traffic affected to be accommodated on other lines?

Consolidation of Passenger Station Switching.

(37) Can you obtain greater efficiency in operation through extending the consolidation of passenger switching:

(a) By combining the switching of two or more roads, using the same station, where each now performs its own switching?

(b) By combining the switching operations of adjacent stations?

(c) By extending any existing joint service to include all switching operation of passenger equipment within the terminal?

(d) By reassigning coach yards so as to reduce haul of equipment to a minimum and to obtain maximum efficiency?

(38) Can an existing freight or other yard and terminal be converted into a purely passenger facility, effecting economy, reducing congestion in both freight and passenger traffic, and decreasing haul of empty passenger equipment?

(39) Can you use wye tracks or loops for turning trains?

Consolidation of Ticket Offices.

(40) Are city ticket offices, other than at stations, so consolidated that all tickets for each road are sold by each ticket clerk?

(41) Are ticket forces now consolidated at stations used jointly?

(42) Can ticket forces of adjacent stations be consolidated to advantage?

(43) Have you analyzed the necessity of continuing city ticket offices outside of stations?

(44) Have you analyzed the ticket sales in the office to develop the relative number of tickets sold to a certain few heavy traffic destinations, with a view of improving the service by confining the sale of such tickets to one or more windows?

(45) Have you considered at depot ticket offices the limited consolidation of sale of railroad tickets to heavy traffic destinations, with the general sale of Pullman tickets, to improve service to the public:

(a) By avoiding the sale of excess railroad fare, for privilege of riding in Pullman cars, to passengers who may later be unable to secure Pullman space?

(b) By avoiding delay to passengers at ticket windows?

(c) By retaining simplicity and accuracy in the internal work of the ticket office, through limiting access to the diagrams to isolated and the fewest possible regularly assigned clerks—whose duties are to mark reservations and both to handle and check cancellations—and providing telephone or other communication between them and window clerks?

Consolidation of Telegraph Offices.

(46) Can you obtain greater efficiency in the use of telegraph facilities of two or more lines:

(a) By further consolidation of adjacent offices?

(b) By using offices of one line in handling trains on an adjacent line?

(c) By through routing of messages?

(d) By consolidating or coördinating relay offices?

(e) By a more general use of the telephone, telautograph, automatic telephone, or other means of transmission; attracting attention by visible or audible signals?

Conversion of Two or More Single-Track Lines Into a Multiple Track System.

(47) Can you convert two or more single-track lines into a multiple track system, establishing currents of traffic, to expedite train movement; to increase safety, capacity and train tonnage; and to promote economy?

Segregation of Freight and Passenger Traffic Upon Separate Tracks Where Traffic is Now Mixed on Several Single or Double-Track Lines:

(48) Have you considered the possibility of consolidating the passenger traffic of several lines, now carried over three or more main tracks, upon two main tracks:

(a) For the purpose of providing a better entrance to a passenger station?

(b) For the purpose of setting free badly needed tracks for use in freight service?

(c) For the purpose of securing freedom from interruption by passenger train movements of freight, transfer or switching movements?

Roadway and Structures.

(49) Have you, with the intensified use of terminals, made proper arrangements for the maintenance and improvement of all yard and main tracks and structures to such standards as will render them reliably serviceable under the new conditions?

(50) Are there limitations of curvature, clearances or other conditions that may interfere with plans of unification in any case?

(51) Are the terminal buildings located and so maintained that the maximum efficiency of the terminal operation may be attained?

(52) Are trains delayed on account of inconvenient or remote locations of billing offices?

(53) Are terminal buildings reasonably accessible to the homes of employes? How should this condition be improved?

(54) Are proper conveniences in the way of rest rooms provided for female employes; and are the buildings properly lighted, ventilated and heated?

"Catechism of Yard Design and Operation."

(55) Are you familiar with the pamphlet entitled "War Emergency Yard Improvements" of the American Railway Engineering Association, issued February, 1918, and are all of the recommendations therein contained being observed in your terminals?

(56) Would not familiarity with the "Catechism of Yard Design and Operation" contained in that pamphlet result in increased efficiency?

(57) Should not a copy of that pamphlet be placed in the hands of each official and employe concerned in yard operation?

SUBJECTS Nos. 3-4.

That the Committee make no report this year to the Association on Subjects 3 and 4.

SUBJECTS Nos. 5-6.

That the Committee has not pursued Subjects 5 and 6 to the extent of being able to offer anything new on the general subject of classification yards, but has made some inquiry as to practices and given the time of one meeting to the discussion of the particular subject of switching from classification yards to departure yards—especially as regards the use of a small sorting yard located between the classification yard and the departure yard.

The Committee finds some conflict of opinion as to advisability of providing such an auxiliary yard, but in so far as it has information, up to this time, provision for such an intermediate yard has seldom been made in yard designs or at any rate in the actual construction of yards.

In some classification yards the sorting of cars into station order or into other similar secondary groupings is accomplished more or less completely by the construction and use of a sorting yard tributary to the hump with its ladder next to the outside track of the main yard and with its short body tracks diagonal thereto. Another method of accomplishing the same thing might be the subdivision of a few of the main classification tracks at one side of the yard by means of intermediate ladders.

Your Committee thus far is impressed with the thought that generally the secondary sorting of cars into station order, etc., can be accomplished satisfactorily by supplementing the classification accomplished via the hump with flat switching performed by trimmer engines either at

the foot of the hump yard or in the departure yard, thus saving the additional investment, the increased length of terminal district, and the delay to cars that would attend their delivery to and removal from the sorting yard, if such an auxiliary facility were provided.

Nevertheless, there may be situations where the construction of an auxiliary sorting yard will be necessary, because it may be impossible to provide sufficient tracks in the classification yard, or because the number of the cars requiring classification into "set out" or placement order may be too great to allow their switching at the departure end of the classification yard, or in the departure yard, without undue interference with the flow of traffic. Such an auxiliary yard should have a sufficient number of tracks of length to conform with the particular requirements of the situation, and where practicable, with assisting grades. In order to minimize the backward movement of cars this yard might be located between the classification yard and the departure yard at one side of the regular current of traffic between these yards. In some cases it is probable an alternate location would be alongside the departure yard.

CONCLUSIONS.

Your Committee concludes:

1. That the preliminary report on Unit Operation of Railroad Terminals in Large Cities including the Catechism on Unit Operation of Railroad Terminals, both printed as advance information in Bulletin, Volume 20, No. 208, August 20, 1918, as revised under Subject No. 2 in this report, be published in the Manual of Recommended Practice.

2. That the matter under Subjects 5 and 6 be received as a progress report.

SUGGESTIONS FOR NEXT YEAR'S WORK.

The Committee recommends that the subjects of this year be continued for next year.

Respectfully submitted,

Committee on Yards and Terminals.

Appendix A.

UNIFIED OPERATION OF TERMINALS.

Abstract from Address Delivered by John F. Wallace Before the Association of Commerce of the United States in Chicago.

The terminal problem is really the big problem of our railroad transportation system, and its solution will automatically solve most of our transportation complexities.

While the total mileage of terminal tracks may not be too much—and in certain localities may even be insufficient—the remedy lies not entirely in additional tracks and facilities, but in a correlation and readjusting of existing facilities and the operation within the terminal zone along lines that will secure the maximum of efficiency.

Viewed from the standpoint of delays, the railway terminal becomes even a larger factor in the transportation problem. The average freight car travels about twenty-five miles a day. The average speed of a freight train between terminals is ten or fifteen miles an hour. It is therefore evident that the average freight car spends twelve hours in the terminal for every hour it spends between terminals.

Since the remedy—whatever it may be—will eventually be applied by Congress, it is highly important that the general public comprehend the fundamentals of the present transportation situation and the general nature of the changes in operation and control necessary to bring about a more efficiently operated transportation system.

These changes will necessarily be of two kinds: First, physical changes in terminal facilities; and, second, changes in method of operation.

The interchange freight should receive first consideration. It frequently happens that a car of commodities consigned from a point in the West to a point in the East is handled successively by several railroads and at every place where it passes from one railroad to another it goes through a terminal, often passing through the hands of an intermediate company, occupying space in several railroad yards, congesting interchange tracks and encountering days of delay.

The remedy for this condition is more direct routing—and a routing that will pass the car around rather than through the larger railroad terminals. Under present practice, a car may be handled miles out of its direct course to destination in order to give a greater mileage to a preferential railroad. Frequently the shipper is equally guilty with the railroad for this condition. The interest of economy demands that the car should pass in as direct a line as possible and with a minimum of delay from point of origin to destination over the most economical route.

To inaugurate unified operation it should be possible—even during the temporary period of Government control—to provide that each railroad terminal zone should be operated as a unit by one local manager. This local manager should take over all of the railroad facilities within the terminal zone and handle all the traffic therein.

Railroads entering the terminal zone should turn over their traffic to the local manager at points designated by him, and he should proceed to handle this traffic to its destination within the terminal zone along the most direct and economic routes and with a minimum of switching and delays. Originating traffic should be handled in the same way.

Appendix B.

UNIT OPERATION OF LARGE TERMINALS.

By H. J. Pfeifer, Chief Engineer, St. Louis-East St. Louis Terminal District.

The railway facilities, existing at the convergence of a considerable number of railway lines, almost always a large city and its environs, constitute a large terminal. It is spread out over an area of two hundred to one thousand square miles in extent, and is usually an industrial center of magnitude. Into, out of and through it pass both passenger and freight traffic.

In a number of large terminals, passenger facilities and operations are already at least partly unified, through the establishment of Union Stations, and where they are not, the cost in money and time of bringing about unification is so great that consideration of the subject, under war conditions, is hardly worth while. Therefore thought and attention should be centered on the unit operation of large freight terminals, with a view to determining what, if any, economies can be secured by this means.

Terminal handling of freight involves two distinct processes, the movement of a car loaded or empty, and its loading or unloading at warehouses, team-tracks, stations, stock-yards, industrial plants, etc.

This discussion will be confined to an attempt to determine the basic principles governing terminal car movement. Assuming that a large terminal is the center of a circle with railway lines radiating toward it, almost invariably, for topographic or other reasons, they approach the terminal in groups and are not uniformly spaced around the circle.

Without unified operation little or no advantage can be taken of this, because under individual operation each line brings its train into its own yard; where it is broken up and reassembled with cars from other trains for delivery to intermediate or direct connections, or for final delivery for loading or unloading on the line itself. Outbound trains are assembled ready for the road by reversing the process just outlined. As every line entering the terminal handles its traffic on the same general basis, much intermediate switching is necessary to affect car interchange between lines, which accounts for the existence of the belt and switching lines and yards in every large terminal. The process of moving a car through a large terminal individually operated is briefly as follows:

The inbound train containing the car enters the yard of the initial line, where it is broken up. The cars of which it consists are regrouped with those of other inbound trains and delivered to local points for loading or unloading, to direct connections, and to intermediate connections, where the regrouping process is repeated one or more times until the car is either in a train ready for movement beyond the terminal limits, or placed for loading or unloading. As cars cannot be econom-

ically moved except in trains of considerable size, no group of cars can ordinarily be transferred from one yard to another until the necessary time has elapsed to accumulate a train large enough for movement.

Intermediate switching, which almost always involves extra car mileage, as well as delay and expense, is necessary, because many, in fact most lines, do not interchange enough cars with each other to justify direct handling, for the reason that trains of sufficient length for transfer do not accumulate rapidly enough. The intermediate line takes cars from and for all, and by reclassifying accumulates trains of sufficient size for economical handling much more quickly than the individual line.

In a system of completely unified freight terminals the control by an individual railroad over its inbound freight train ceases with its delivery on a receiving track in an assigned yard, within the terminal limits, and does not begin over its outbound train until it is built up complete in readiness for road movement; all intermediate service of every nature is performed by the terminal organization. It can readily be seen that the more railroads there are, and the greater the extent of the industrial district served, the greater and more complicated is the service to be performed.

With unified terminal operation, facilities are so arranged that a number of lines deliver and receive their trains with road power in the same yards.

For example, roads A and B are so close to each other that the trains of one can enter the yards of the other with little if any excess mileage or expense. Each road has its own inbound and outbound yard system. By assigning the yards of one for inbound, and of the other for outbound movements, the following will result:

The volume of traffic between the consolidated yards and every other point in the terminal is the sum of that between the individual yards and those points.

The number of classifications to and from the consolidated yards will be reduced 50 per cent., and as a consequence the number of cars assembled in each classification in a given time will on the average be doubled.

As each road now builds up its trains in its own yard for road haul, after delivery of cars by connecting lines, there is no increase in the number of classifications required for outbound movement.

If three or more lines are consolidated into one yard the number of classifications will be proportionately decreased and the number of cars assembled in each classification proportionately increased.

If roads A and B consolidate their yards and C and D do likewise, the number of classifications moving between them will be in the ratio of one for the consolidated yards to four for the individual yards, and the number of cars assembled in each classification in a given time will be four times as great.

If six or more lines consolidate in pairs, the ratio of classification will still be one to four, and number of cars in each classification four to one.

If, however, six, nine, or more lines consolidate in groups of three each, the ratios become one to nine and nine to one, respectively, and with groups of four, one to sixteen and sixteen to one, respectively, and so on.

It can readily be seen from what has just been said, that if a large terminal is arranged so that the number of yards between which cars are transferred is reduced, the number of cars moving in transfer, between each pair of yards in a given time, is increased; provided the volume of traffic remains constant. It is also true that the number of cars, moving in any transfer route in a given time, is approximately inversely proportionate to the square of the number of yards served by them. In other words, if a given car movement is handled through five yards, there will be sixteen times as many cars in each transfer between yards in a given time as if the same volume of traffic were handled through twenty yards.

A consolidation as great as this would practically eliminate all intermediate switching and make possible the passing of cars through the terminals with two classifications—one to break up the train as it comes from the road or local point, and the other to build up the train ready for the road or delivery to the local point.

The economies in time and expense resulting from such a consolidation are many and varied, as follows:

Elimination of one or more intermediate classifications, resulting in a saving of car days, car damage, extra switching expense, locomotive hours and many other sources of delay and expense. The money value of these savings depends, of course, on the size of the terminal and the reduction in complexity of service it is possible to bring about through yard consolidations. That it will involve savings in time and expense aggregating a value of millions annually in some of the larger terminals is not an unreasonable expectation.

A unified terminal, such as is suggested, may be compared to the telephone system of a large city. Each classifying yard corresponds to a central exchange—the yard forces to the telephone operators; the yard itself and the locomotives to the switchboard; the transfer tracks between yards to the main trunk lines between exchanges and the cars to the messages. Here, however, the comparison ends, because cars cannot be transferred singly, but must be held until a sufficient number have accumulated to make a train of proper size.

As the movement of a car through a terminal, or over a road, is governed by its destination, regardless of its origin, the following general principles governing the expeditious and economical movement of freight cars through a large terminal, are suggested:

A—The train being the unit in which car movement is conducted between two points, cars moving to common points should be gotten

together at as early a stage in their movement as possible, and kept together as long as possible. Therefore, if two or more lines come into a terminal from the same general direction their trains should enter a common yard, so that cars moving to common points in the terminal can be put together.

B—As cars can be kept more closely together in a small group of yards, the number of classifying yards should be maintained at the minimum, consistent with the movement of cars by reasonably direct routes.

C—As a given number of cars will accumulate in trains of proper size, to be moved, more rapidly with a small number of classifications, the minimum number consistent with securing the required separations should be used.

D—As intermediate switching involves loss of time and extra expense, car movement should be consolidated as much as possible to reduce it to a minimum.

The system of terminal operation above outlined is susceptible of indefinite expansion as the traffic increases, without adding yards in new locations with resultant changes in the routing of cars, provided that the general direction of flow of traffic remains the same. The classifying yards may be duplicated again and again in the same manner that additional units are added to sectional bookcases and filing systems, if one unit is too small.

If extensive new territory is developed or a distinct group of new lines enters the terminal, yards in new locations may become necessary.

The suggested system of operation reduces the number of yards in which classifying service is performed, and a number of yards in every large terminal will be abandoned as classifying yards. They can be used for the storage of cars classified or unclassified if that is necessary; the holding of cars for prospective loading or for any similar purpose.

It would seem possible to so arrange and consolidate the use of existing yards and other facilities in every large terminal without incurring any large construction expense, and thus bring about great saving in car handling and classifying expense. These savings mean a reduction in locomotive hours, car damage, clerical expense, car days consumed and in many other ways.

A careful and detailed study of each large terminal, with a view of determining what can be done toward securing operating economies along the lines above described, would, in the opinion of the writer, be fruitful of results of enormous value to the Government and transportation interests of this country.

Appendix C.

IMPROVEMENT IN OPERATING METHODS OF INTERMEDIATE TRANSFER RAILROADS.

BY E. H. LEE, PRESIDENT, CHICAGO & WESTERN INDIANA RAILROAD COMPANY.

It is the opinion of many well-informed railroad men that the transportation work to be performed by the railroads of the country during the coming winter will be from 20 to 40 per cent. greater than that performed last winter, if traffic conditions reasonably to be expected are to be met. This increase in transportation work is caused largely by reason of the various Governmental activities necessary in the work of winning the present war, although the ordinary business of the country is keeping up in surprising volume. The need for fuel is greater than ever, although that portion handled along our eastern seaboard by vessel must now be handled by rail. Prompt deliveries of other war materials in heavy volume are imperative if the work of properly maintaining and supplying our fighting force abroad is to continue. Food materials and products must be moved to the seaboard promptly and troop movements are increasing the demands upon the passenger facilities of the country.

It is the purpose of this article to discuss the existing situation on the railroads of the country with a view to determining what can be done within the next four or five months toward improving existing conditions, in order that the railroads may be more nearly able to meet the demands that will then be made upon them.

It may be well to briefly review the conditions as they now exist, although such a review will contain a statement of facts which are well-known to most railroad men, and are coming to be better known by the general public, and which may therefore seem more or less trite.

Until about ten years ago the railroads of the country expended great sums of money for double track, the reduction of grades, the extension of sidetracks, the construction of new branch lines, and other facilities for accumulating traffic and handling it more expeditiously to the terminals, without any corresponding expenditure to improve facilities in the terminals themselves. Recently more of an effort has been made to improve and enlarge terminals; but on many of the railroads the important terminal facilities in the larger cities are in great measure what they were ten years ago. Although from the nature of the case, since early in the history of the railroad industry, terminals have been the principal points of congestion, this tendency has become greatly aggravated during recent years. It is not too much to say that at this time the capacity of the larger terminals of the country are the measure of the transportation output which can be delivered by the railroads. The railroad system of the country may be compared to a system of canals in heavy use for water transportation, consisting of open channels

interrupted more or less frequently by locks; in which the open channels have been widened and deepened and made suitable for a still heavier traffic without any corresponding change in the size or capacity of the locks. In that case the locks offer an impediment to the flow of traffic, and their capacity determines the capacity of the canal itself. Even the open country facilities of the railroads have not kept pace with the growth of the general business of the country, for reasons which are well understood and need not be mentioned here. For the same reasons, the maintenance of tracks, motive power and car equipment have been rigidly kept to the lowest standard compatible with safety, so that as a general average little or no reserve maintenance has been accumulated during the last ten years.

A comparison of the consumption of steel rails during the last 20 years with the growth in mileage of all track and the growth in the tonnage handled shows the tendency referred to and gives some idea of the deficiency which exists in this item of track maintenance. This consumption is fairly well shown by the following figures, which are the result of an equated curve derived from a graphic statement furnished by the courtesy of Robert W. Hunt & Company:

	Consumption Tons.	*Total Track Miles.*	*Gross Earnings.*
1898	1,000,000	245,000	$1,247,000,000
1907	3,000,000	328,000	2,440,000,000
1917	2,100,000	395,000	4,041,000,000

In an article written for the Iron Age by C. W. Gennet, of that company, it is estimated that the deficiency in rail renewals the country over at the present time amounts to a total of approximately 10,000,000 tons The difficulty in securing rails for the use of the railroads at the present time is also shown by the fact that for the year 1917 the average rollings of steel rails at the mills were 54,000 tons per week, whereas for the ten weeks preceding July 20 the average rollings were only 30,000 tons per week, and from this 30,000 tons it is fair to presume that a considerable quantity may have been required for use abroad.

The transportation work of the country is being handled by the railroads at the present time in greater volume than ever before and with reasonable dispatch. It will be remembered, however, that conditions in the summer season lend themselves to maximum transportation effort, whereas during the winter season this maximum effort is necessarily reduced. Storms interfere with the regular flow of traffic and low temperature reduces maximum trainloads, develops hidden defects in the maintenance of motive power, and cause delays in the transportation process in many different ways. Railway men generally appreciate that just as the destruction of the poor is their poverty, so congestion on the railways propagates itself rapidly and causes further congestion.

In the last analysis congestion is the chief enemy of railroad transportation because it interferes with the one purpose of the railroads—the movement of traffic.

In the manufacture of transportation, i. e., the movement of traffic, certain things are fundamentally necessary to secure good results. Some of these are financial ability or credit; adequate facilities, including tracks, motive power and car equipment, together with their various appurtenances; good organization and discipline; and good transportation methods and practices. A sound management for any railroad secures all these things in so far as possible. As to credit, the Federal Government is now behind the railroads of the country.

It will doubtless be conceded that the facilities of the railroads are relatively much greater for handling traffic outside the more important terminals than within them, and therefore the inference seems plain that in order to secure the maximum improvement, any measures looking toward an increase in their capacity for handling traffic next winter should be directed toward the terminals rather than toward the open country lines.

If prompt authority is secured, yards for the storage of cars may be provided either adjacent to, or at points outside of and beyond important terminals, where land is cheap and construction is easy, and this car storage, if provided, will doubtless be of great value in keeping tracks in working yards sufficiently clear, so that they may be reasonably open for the receipt and necessary classification of business. It seems certain, however, that the only improvements in track facilities which can reasonably be expected to be available next winter within the larger terminals themselves will be those secured by so-called coördination, with the better balanced and therefore more complete use thereby secured. Experience has shown, however, that any rearranged use of existing track facilities should be carefully investigated, and adopted with caution, because many cases have and will occur in which suggested changes are only of superficial advantage and would probably be an actual disadvantage, considering the situation as a whole.

Energetic efforts are being made to repair the motive power of the railroads, and if the need arises the Federal Administration will be in a position to draw in power from the open divisions of the railroads for use in terminals where congestion is most intense. It is also to be expected that repairs to existing car equipment will be vigorously prosecuted. This is necessary and desirable, although it seems evident that car equipment, in excess of the motive power and track room in important terminals to handle it, will be of little or no aid to the general situation.

The various railroad organizations of the country have been consolidated under the new Federal control. Before the Government took over the operation of the railroads these organizations differed to a very considerable extent, both as to general character and efficiency. In some

organizations ability, knowledge of human nature, courage and fair dealing on the part of the officers were rewarded by good discipline, loyalty, company-spirit, and team-work, among the rank and file. Corresponding results in the way of efficient work, maximum output and minimum cost were secured. Other railroad organizations may suggest themselves where the conditions have not been so fortunate. Efficient organization and discipline are apt to be of slow growth, and are the result of intelligent and long-continued effort. The inference seems reasonable that, particularly in view of the more or less unsettled condition inherent to the recent change of control, no general change can be expected within the next five months in the general standard of efficiency of the various railroad organizations, and that those which are good will continue good and those which are otherwise will so continue.

Of the requirements mentioned as fundamentally necessary for the efficient manufacture of transportation only one remains, viz., good methods and practices. It is just here, in the view of the writer, that important changes and improvements may be made which will quite radically improve the efficiency of the railroads as a whole, because they will reduce congestion in the terminals, this being, as already stated, the chief enemy to transportation efficiency as a whole.

Congestion is defined as a condition of undue pressure, a state of unnatural crowding; and congestion on the railroads, like congestion in the body, is a disease which interferes with the normal functions, and is to be reduced by the use of various devices and means adapted to remove the undue pressure in the parts affected. Two of the principal causes of congestion in terminals, which in turn act in a vicious circle with congestion itself, each to cause the growth of the other, are dead time and the rehandling of cars. It is safe to say that any method or practice which secures the maximum reduction in dead time, and in the rehandling of cars, will also secure maximum reduction in the congestion of terminals, and therefore maximum increase in the efficiency of the railroads of the country as a whole.

For the purpose of this discussion, dead time is limited to and may be defined as time spent by the train crew after an engine has been manned, in getting out of the roundhouse, pulling up to and coupling onto the train, testing the air, etc., at the outgoing end of the trip; time lost in setting out and picking up; and time spent in putting away the train, with the various similar attendant operations at the incoming end. This so-called dead time thus defined is to be distinguishable from time spent in actually passing over the road. Its serious effect in terminaal operation is not generally appreciated, being of much less relative importance in open country operation than in terminal operation. This is true because dead time remains more or less constant, while running time tends to vary directly with the length of the run. As an illustration: Assume an open country division 100 miles long, average freight running time over the division 8 hours; as compared with a transfer run

in a terminal 12 miles long, average running time 1 hour. If the dead time is in each case two hours, the dead time loss on the country division is only 20 per cent., whereas on the transfer run it is 66⅔ per cent. This comparison may seem exaggerated, but an investigation made by the writer some years ago, which is believed to have been reasonably accurate, disclosed that in an actual case under ordinary conditions and where no undue congestion existed dead time as above defined consumed 65 per cent. of the total service time of all transfer trains.

Rehandling cars is brought about by a number of different causes. Lack of proper method, as well as lack of careful and intelligent planning on the part of Trainmasters, Yardmasters, and Conductors responsible for transfer movements, is partly responsible, but these causes operate during times of normal movement as well as during times of congestion. The great cause for rehandling is undoubtedly congestion, which is in turn further aggravated by the rehandling itself.

The two chief requisites for the rapid and efficient classification of cars, in so far as facilities are concerned, are sufficient motive power and sufficient open track room. The best results are obtained when these two kinds of facilities exist in a proper ratio. It is well understood that a deficiency in track room may up to a certain point be equalized by a surplus of motive power, but that this can only be done at the expense of additional rehandling, with the consequent increase in congestion. On the other hand, it is hardly necessary to observe that a surplus of open track room will not make good a deficiency in necessary motive power.

If the foregoing discussion is reasonably accurate as to the facts it may be continued with a view to determining their application and as to what changes may be advantageously made in prevailing methods and practices in order to secure an improvement.

At most minor terminals and junction points, direct deliveries are made between the railroads, and at some points the chief improvement possible is doubtless to be secured by a coördination of facilities when practicable, and an improvement in methods, as, for instance, by the reciprocal delivery of cars, thereby eliminating light running. In the case of industries served by more than one line, it has been the general practice in the past for each road to handle its own business into and out of the same, although in one case familiar to the writer all such industrial deliveries have been handled by a terminal railroad for the tenant companies using its line for a period of over 30 years, and with results entirely satisfactory in the way of a reduction of both engine time and cost. Under the new Federal operation an arrangement has been inaugurated at various points by which the business of all the railroads to and from a certain industry or group of industries is handled by one company, and this practice may be expected to become general.

On the other hand, in the terminals of many of the larger cities considered as a whole one or more transfer railroads have performed an

important part in the process of receiving and delivering cars between the various lines, and these transfer railroads become especially important during times of congestion. The transfer of cars in small terminals and at junction points is relatively a simple matter, and with proper care and attention, on the part of the railroad officers familiar with the conditions, it ought to be put on a more uniformly satisfactory basis. The transfer of cars over a transfer railroad in a large terminal is more complicated, and in view of the difference in the service performed, as between railroads of this kind, an analysis in each case would seem desirable, to determine what changes are needed. One of the broader differences is that some transfer railroads are used entirely for the operation of trains handled by the motive power and train crews of their tenants, while others operate either in whole or in part with their own power and crews. As the more important transfer roads in large terminals are operated in the latter way, what follows in this discussion is considered as especially applicable to them.

Certain principles follow with the reasons therefor which are believed to be particularly applicable to terminal transfer railroads which operate trains with their own power and crews, although some of these principles are of more general application:

1. The operation of transfer railroads should usually be restricted as much as possible to the transfer of cars as distinguished from the classification of cars. It follows that the through line should so far as practicable deliver its cars to the transfer line classified and straightened out into cuts for the various through lines to which deliveries are to be made by the transfer line for through line account. Such a transfer railroad as is being considered may be compared to a thoroughfare connecting two camps or cantonments. It may be of ample width to handle all the travel between them, if team and foot travel is kept moving in column formation, at fair speed, and without unnecessary steps, columns having been formed in the streets and areas of the cantonments themselves. But if the thoroughfare is used as a drill ground, for the formation of columns, or as a recreation area, its capacity may be reduced to the vanishing point. The main tracks of most transfer railroads are ample for a larger volume of traffic than is handled over them, but in times of congestion they are frequently blocked at junction points, yard entrances and connections by trains which are unable to get into yards by reason of their crowded condition. These yards, in turn, are congested by an oversupply of cars awaiting classification, which occupy room which should either be reserved for the receipt of main line transfer trains or which should be kept for the classifications which are necessary and which cannot be made to advantage elsewhere.

It should be observed that where through lines make direct deliveries to each other, they classify cars straight for the various railroads as a matter of course. There seems no good reason why when delivery is made through the agency of a transfer line the through line should not continue to make the required classifications, at least to a reasonable extent. In so far as the through business is concerned, it is believed that the practice of considering and using the transfer line as an agency for both classification and transfer, instead of restricting its use so far as practicable to the transfer of cars, is responsible for much of the congestion of terminals. The present practice has been the growth of years. Until recently the transfer road depended upon the through lines for much of its business, and felt in no position to object to the dumping of business upon it regardless of congestion or of how badly the deliveries might be mixed. Under the old conditions the responsibility of the through line ceased once it had delivered its cars to the transfer or belt line, and every effort was accordingly made (the more congestion increased, the more strenuous the effort) to unload on the transfer line, regardless of ultimate consequences, thus "shifting responsibility."

With flat switching ordinarily eight or ten classifications are made without rehandling, a greater number being bunched and reclassified. An analysis will show that in very many cases only few classifications are required to straighten out a large proportion of the business. In one case in Chicago about 50 per cent. of the through transfer business in one direction goes to only two railroads. If all cars for these lines were delivered to the belt line in straight cuts, approximately 50 per cent. of the classification in that direction would disappear and much of this 50 per cent. could be run in straight trains from terminal to terminal, thus eliminating dead time and helping to keep yards clear. Moreover, this preliminary classification could be made with little or no additional expense by the through line, because it must in any event switch out many cars, such as bad orders, holds, and those for other deliveries. Also a considerable amount of this preliminary classification could be done to advantage at the division yards of the through line beyond the large terminals.

The place to control congestion is at or near the various points where business originates. By proper measures the through line may in a degree control congestion in its own important terminal yards, by holding back business, something impossible to the belt line, without the help of the through lines.

Business moving even in heavy volume is not congestion, and where they exist, belt lines if kept reasonably open and uncongested are the best means of keeping cars moving in terminals, thus avoiding congestion and blockades.

Preliminary or advance classification as above described is not a theoretical measure, but has been used with success to prevent and to lift blockades in terminals, many times.

2. Where transfer or belt roads are of considerable length and where equipped with motive power to handle transfer trains, it is the better practice to keep foreign engines off the belt line, performing the transfer service with belt crews. Better supervision can be secured where train crews are kept at home. It is difficult, if not impossible, to enforce discipline over crews while operating on a foreign road (particularly against loafing on the job), even though in theory they become the employes of that road while so engaged. Moreover, discipline and standards of performance differ on different railroads, being better on some and worse on others. Where foreign trains and engines operate over a transfer road it ordinarily happens that the general movement is regulated by the slowest and most indifferently operated train. There is also a difference in the standard of power maintenance as between railroads. A stalled train caused by the engine breaking down, not steaming or being overloaded, delays all following trains, and if a foreign crew, the railroad officers who should apply discipline have no direct stake in the failure, and find excuses ready to hand. The practice of using foreign crews on the transfer road is not sufficiently elastic. The crew may have a full train in one direction and a light train in the other, because it runs between two points only. The belt crew may be ordered to any one of several different points, as the business may indicate.

3. Trains should be so made up that one engine will handle as many cars as far as possible.

This principle is used in the operation of through lines very generally. Under the new Federal operation trains of war material have been consolidated and run solid over several different railroads without breaking up, with a saving of time and expense. The application of the principle on transfer railroads is even more important than on the through lines, because it is one of the best ways of reducing dead time, which, as we have seen, cuts so much more figure on the belt line than on the through line.

4. Where track facilities permit, the through line engine should make deliveries to the belt line yard and should haul back its own deliveries from the belt line yard. This eliminates light running. It also fixes responsibility, something of great importance during times of congestion because it permits the prompt application of the remedy. This presupposes that the belt line has sufficient tracks for both its receipts and deliveries, which will doubtless be true in most cases, where its yards are kept properly clear. As the receiving road controls its own receipts, this arrangement would give control of both receipts and deliveries to the belt line, because unless the through line keeps its receiving tracks clear by taking its business, the belt line can shut it off, and this is as it should be.

5. Transfer trains should be loaded to capacity so far as practicable, because a light train costs about as much and occupies the track facilities to about the same extent as a full train, while handling less cars. No discussion seems necessary of this rather obvious principle, although it is not always carried out in practice.

As will be observed, the foregoing discussion is largely directed toward an improvement in the operating methods of an intermediate transfer railroad. How important transfer railroads of this type are to the business of the country is shown by figures prepared by the writer in 1915 regarding one of the Chicago Belt Lines. With a roadbed mileage ot only .012 per cent. of the mileage of the whole country, it handled a tonnage equivalent to 1.03 per cent. of the total tonnage of the country. Bearing in mind that terminal congestion retards the flow of traffic for long distances outside the terminals as a dam cuts off the flow of water for miles above it, the vast importance of removing congestion and promoting the flow of traffic through terminals becomes apparent.

It may also be observed in conclusion that some of the improvements suggested as applicable to belt or transfer railroads, will be found of equal advantage in connection with the work of terminal divisions of some of the larger systems.

The three things among those suggested in this discussion which it is believed would have especial effect in controlling congestion are the construction of storage yards, outside the terminals; the advance classification of transfer cars, to the greatest practicable extent; and an extension of the authority of the men in charge of terminal operations, whatever their rank or title, in order that they may better control the flow of traffic to and through the terminals.

Appendix D.

THE TICKET SELLING PROBLEM.

By Miles Bronson, Terminal Manager, Grand Central Terminal, New York Central Railroad.

We have at Grand Central Terminal probably as complicated a ticket-selling problem as exists at any railroad station in the United States. The original design of the Terminal presumably provided adequate facilities and considerable leeway for the future, but as a matter of fact we some time ago got to a point where, during maximum periods, we had an insufficient number of windows. We have considered the matter from all angles, and have tried to defer as much as possible rather important and far-reaching constructional and architectural changes which would be necessary in order to increase the facilities. As a result of our studies we some time ago arrived at the conclusion that so far as we are concerned segregation of various classes of ticket selling is a bad arrangement, and that every window should be a universal ticket office, dispensing anything and everything that could be obtained at any other window. Our present arrangement divides the available space for each railroad into three classes, viz: local, through and Pullman. We are having built, and expect shortly to install on the New York Central side, and probably later on the New Haven side, a new type of ticket case, designed for us by Alfred Fellheimer, Architect, which will not only make it possible to provide a complete stock of every kind of tickets, including Pullman, at every window, but the ticket cases themselves, will be units, which can be readily locked up, and portable, so that they can be easily moved. We propose to furnish every ticket seller with one of these cases, which is charged to him; all the available windows are to be common. The idea is that when one man goes off duty, or is obliged to absent himself, except momentarily, and even then under maximum conditions, he will first give notice and then close his case and remove it, and another man will move up his case, open it, and proceed to take care of the public. By this means we expect to increase the use of our ticket windows at least 30 per cent., thus postponing the day somewhat when additional ticket-selling facilities will have to be provided.

This type of ticket case has been installed and is now in service at the Railroad Administration Consolidated Ticket Office, No. 64 Broadway, New York, and is apparently justifying our confidence in it. The opportunity for comparison between it and the old-style coupon or interline ticket cases is excellent at that office, as all the other companies represented at that office installed the old-style case.

We have also installed another innovation in connection with the handling of the Pullman diagrams. An entirely separate room, somewhat remote from the ticket office, has been provided and equipped with proper telephone facilities and racks for the diagrams, and we are now handling 50 per cent. of all the Pullman space on New York Central

trains out of New York at that office. As soon as we get the Fellheimer ticket cases installed we propose to take out the remaining 50 per cent. of space from the ticket office proper and handle that also at the new Pullman office.

Under this system a ticket seller gets the desired Pullman space, by direct intercommunicating telephone connections, in the presence of and without turning away from the ticket buyer, and we find, as we expected to, that this is a much faster method than the old arrangement.

I realize, of course, that this Pullman arrangement is not feasible for a great many smaller offices, but I cannot express myself too strongly in favor of the Fellheimer ticket case for any office, whether it sells only local, or combinations of local, interline and Pullman.

Appendix E.

THE TICKET SELLING PROBLEM.

By B. W. Frauenthal, General Passenger and Ticket Agent, St. Louis-East St. Louis Terminal District.

Our experience has proven that, in so far as this office is concerned, the system of designating certain windows for one particular class of business is very unsatisfactory. In order to do this, certain windows must be assigned to suburban travel, others to coupon, local, etc., and as a rule the public do not look at signs but invariably ask the seller to point out the proper windows for the class of ticket they may desire. When the time and inconvenience is considered, the passenger can be handled much more satisfactorily by the seller first approached than by compelling the passenger to seek another window. Furthermore, the sellers in one set of windows may have more work than they can handle at certain hours of the day, and the other windows be idle, or vice versa. By handling all passengers, the sellers are kept busy at all times, and the passengers suffer no inconveniences. Sellers also become proficient in the sale of all kinds of tickets and not limited to any particular kind of ticket, thus permitting us to use any of the men, in any position, at any time.

In our opinion, the handling of Pullman tickets should be improved by providing plenty space and proper facilities, permitting all diagrams to be retained at the Union Station ticket office, obviating the necessary expense and trouble of carrying the diagrams from the city offices or the Consolidated City office to the station, where they eventually must come.

Of course, our present quarters are not arranged and the space is insufficient to properly install such a system, but our suggestion would be to have a large case constructed with separate compartments, exactly the size of the Pullman diagrams, with an opening at either end, so that diagrams would be easily accessible from the selling side or from the opposite side, where as many employees as required would be stationed with telephone equipment to take care of Consolidated City office calls. For example, should one of our sellers have a request for ticket and berth, he would remove the diagram from the selling side, insert the ticket number and return the diagram to its proper compartment. If the Consolidated City office should call for space, the telephone man would remove the diagram, insert the ticket number and return to its proper place.

This arrangement would minimize the number of redeemed tickets, and prevent much inconvenience to passengers, as under the present system the passengers must secure railroad ticket before purchasing sleeping car ticket. He afterwards finds no space is available and must have the ticket redeemed in order to purchase via some other route; whereas, if

Pullman tickets were kept in the Union Station ticket office, the seller would ascertain if space is available before selling the railroad ticket.

It is obvious that this system would require an increased force in this office, and our present space would be entirely inadequate, as well as improperly arranged. However, we believe this is the correct solution to the Pullman problem in relation to the railroad ticket proposition.

REPORT OF COMMITTEE XVIII—ON ELECTRICITY.

EDWIN B. KATTE, *Chairman;*
A. G. SHAVER, *Vice-Chairman;*
A. H. ARMSTRONG,
H. M. BASSETT,
Z. M. BRIGGS,
D. J. BRUMLEY,
H. M. CHURCH,
C. S. CHURCHILL,
R. D. COOMBS,
WALT DENNIS,
R. H. FORD,
W. F. GRAVES,
G. W. KITTREDGE,
C. E. LINDSAY,
H. K. LOWRY,
W. L. MORSE,
W. S. MURRAY,
FRANK RHEA,
J. R. SAVAGE,
M. SCHREIBER,
H. U. WALLACE,

Committee.

To the American Railway Engineering Association:

Your Committee presents herewith its Annual Report for the year 1918.

The following outline of work was assigned to the Committee on Electricity by the Board of Direction:

SUBJECTS ASSIGNED.

1. Make critical examination of the subject-matter in the Manual and submit definite recommendations for changes.

2. Report on the study of electrolysis and insulation and its effects upon reinforced concrete; report upon methods of insulating or guarding against electrolysis.

3. Report on the study of maintenance organization and on relation to track structures.

4. Report on utilization of water power for electrical railway operation in collaboration with Committee on Conservation of Natural Resources.

5. Report recommended practice for eliminating, as far as practicable, the interference with telephone and telegraph lines caused by the use of propulsion circuits.

6. Continue co-operation with National Joint Committee on Electrolysis and the National Joint Committee on Overhead and Underground Line Construction.

COMMITTEE MEETINGS.

Three meetings were held in Room No. 5048, Grand Central Terminal, New York City, as follows:

First meeting was held on August 7, and the following were present:

E. B. Katte, Chairman,
H. M. Bassett,
Z. M. Briggs,
D. J. Brumley,
C. S. Churchill,
W. L. Morse,
L. S. Wells, representing Mr. J. R. Savage.

At this meeting Sub-Committees were appointed and the work for the year outlined.

The second meeting was held on November 20, and the following were present:

E. B. Katte, Chairman,
A. H. Armstrong,
C. S. Churchill,
W. L. Morse,
W. S. Murray,
M. Schreiber,
L. S. Wells, representing Mr. J. R. Savage.

At this meeting preliminary reports of Sub-Committees were read, revised, and the work of rounding out the reports detailed.

The third meeting was held on December 30, and the following were present:

E. B. Katte, Chairman,
A. H. Armstrong,
Z. M. Briggs,
R. H. Ford,
W. L. Morse,
M. Schreiber,
L. S. Wells, representing Mr. J. R. Savage.

At this meeting the reports of the Sub-Committees were received and the report to the Association compiled as follows:

(ITEM 1) REVISION OF MANUAL.

Sub-Committee No. 1.

R. H. Ford, Chairman;
A. H. Armstrong,
C. S. Churchill,
R. D. Coombs,
W. F. Graves,
G. W. Kittredge,
C. E. Lindsay.

The Committee last year submitted to the Association a list of technical definitions and the Association tentatively adopted and published them in the Proceedings with the understanding that the membership would have an opportunity to consider and offer suggestions to the Committee. The following list of definitions has been revised and is now submitted for adoption and printing in the Manual. These definitions, so far as possible, conform with those in use by the U. S. Bureau of Standards and printed in the National Electrical Code and those of the American Institute of Electrical Engineers. It will be noted that the definitions are arranged in alphabetical order rather than in logical sequence. This has been done with the view of conforming to common usage in the Manual. Words in parentheses after each definition indicate new definitions by the word "proposed" or the source of existing definitions.

Electrical Definitions.

Bond.—A metallic means for connecting conductors to permit passage of electric current. (Proposed.)

Bonder.—An employee assigned to install or maintain bonds and their appurtenances. (Proposed.)

Bracket Support.—An arm supporting the trolley wire or catenary. (Proposed.)

Bridge Support.—A rigid overhead structure supporting the trolley wire or catenary. (Proposed.)

Cable Conductor.—Wires bound together acting as a conductor. (Proposed.)

Catenary Suspension.—Any form of trolley construction supported by a longitudinal wire or cable. (Proposed.)

Clearance Line (Equipment).—The line beyond which no part of the equipment shall project. (Proposed.)

Clearance Line (Third Rail).—The line beyond which no part of the third rail structure shall project. (A. R. E. A. Manual.)

Conductor.—A metallic path for the flow of electricity. (Proposed.)

Contact Conductor.—That part of the distribution system other than the traffic rails which is in immediate electrical contact with the circuits of the cars or locomotives. (A. I. E. E. 706.)

Contact Rail.—A rigid contact conductor. (A. I. E. E. 767.)

Contact Rail (Overhead).—A rigid contact conductor above the elevation of the maximum equipment line. (A. I. E. E. 768.)

Cross-Span Support.—Overhead wire or cable supporting the trolley wire or cantenary. (Proposed.)

Direct Suspension.—Any form of overhead trolley construction in which the trolley wires are attached by insulating devices directly to the main supporting system. (A. I. E. E. 780.)

Distributing System.—That portion of the conductor system which carries current of the kind and voltage received by the cars or locomotives. (Proposed.)

Duct Line.—A structure consisting of one or more tubes and chambers for the housing of wires or cables. (Proposed.)

Jumper.—A cable used to connect the ends of two contact conductors. (A. R. E. A., Vol. 18, page 145.)

Patrolmen.—Employees assigned to inspect track and third rail structures, cables and wires. (Proposed.)

Pulling Chamber.—A chamber in a duct line provided for pulling cables and wires into ducts. (Proposed.)

Splicing Chamber.—A chamber in a duct line, in which cables are spliced and inspected. (A. R. E. A., Vol. 18, page 144.)

Substation.—A structure and its contained group of apparatus or machinery which receives current from a transmission system, changes its kind or voltage and delivers it to a distribution system. (A. I. E. E. 762.)

Third Rail.—A contact conductor placed at either side of the track, the contact surface of which is located a few inches above the level of the top of the track rails. (A. I. E. E. 769.)

Third Rail Gage.—Distance measured parallel to plane of top of both running rails between gage of nearest running rail and inside gage line of third rail. (A. R. E. A. Manual.)

TRACTION LINEMEN.—Employees assigned to install or maintain wires and cables and their appurtenances for all railroad voltages. (A. R. E. A. Manual.)

LINEMAN (New).—Employees assigned to install or maintain wires and cables and their appurtenances. (Proposed.)

TRANSMISSION SYSTEM.—That portion of the conductor system carrying current of a kind or voltage different from that received by the cars or locomotives. (Proposed.)

TRANSMISSION LINE.—A system of towers or poles and cables or wires carrying current from the source of power to the substations. (Proposed.)

TROLLEY WIRE.—A flexible contact conductor customarily supported above the cars. (A. I. E. E. 777.)

CLEARANCES—THIRD RAIL AND OVERHEAD.

SUB-COMMITTEE No. 2.

H. M. Bassett, Chairman;
Z. M. Briggs,
W. F. Graves,
H. K. Lowry,
A. G. Shaver.

This Sub-Committee makes no report this year, but has kept its organization intact with a view of revising and bringing up to date the statistical tables contained in the report of last year, and will present them to the Association in March, 1920.

TRANSMISSION LINES AND CROSSINGS.

SUB-COMMITTEE No. 3.

R. D. Coombs, Chairman;
H. M. Bassett, Vice-Chairman;
D. J. Brumley,
H. K. Lowry,
Frank Rhea,
J. R. Savage,
A. G. Shaver.

This Sub-Committee has kept itself advised in relation to the transmission line crossing requirements of the proposed National Electrical Safety Code and is prepared to confer with the representatives of the American Railroad Association and American Electric Railway Engineering Association with a view of revising the joint transmission line crossing specifications, as soon as the representatives of the other associations are appointed.

(ITEM 2) ELECTROLYSIS AND INSULATION.

SUB-COMMITTEE No. 4.

E. B. Katte, Chairman;
D. J. Brumley,
R. D. Coombs,
H. M. Church,
C. S. Churchill,
W. S. Murray,
M. Schreiber.

This Sub-Committee has no report to offer on Electrolysis and there has been no meeting of the American Committee on Electrolysis during

the past year. The Sub-Committee has kept in touch with the subject of electrolysis in reinforced concrete in salt water, but nothing new has developed which can be reported at this time.

(ITEM 3) MAINTENANCE ORGANIZATION AND RELATION TO TRACK STRUCTURES.

SUB-COMMITTEE No. 5.

Walt Dennis, Chairman;
Z. M. Briggs, Vice-Chairman;
H. M. Church,
R. H. Ford,
C. E. Lindsay,
W. L. Morse,
J. R. Savage.

This Sub-Committee has kept in touch with current developments, but defers reporting until next year.

(ITEM 4) WATER POWER.

SUB-COMMITTEE No. 6.

C. S. Churchill, Chairman;
Z. M. Briggs, Vice-Chairman;
A. H. Armstrong,
H. M. Church,
D. J. Brumley,
R. H. Ford,
W. S. Murray,
Frank Rhea,
M. Schreiber.

This Sub-Committee has to some extent investigated the utilization of Water Power for electric railway operation and has collected some data to indicate to what extent water power is now used to generate electricity for the operation of steam railroads. In the table below are shown the principal steam roads which have been partially electrified, the source of power, and the approximate annual current consumption. In the case of those roads using current generated by steam, the reason why water power was not used is given so far as obtainable.

ELECTRIFIED STEAM RAILROADS—1917.

Line	1917, Miles Electric Track	Trolley Voltage	Kind of Service, Passgr. and Freight	Power From	KWH 1917 at Power House for Trains	Reasons for not Using Water Power
Penn. R. R., N. Y....	97	650 DC	P	Coal	64,290,840	None available.
L. I. R. R., N. Y....	208	650 DC	P	"	97,382,970	None available.
P. R. R., Philadelphia.	95	11000 AC	P	"	23,100,360	None available.
W. J. & Seashore....	150	650 DC	P	"	32,825,600	None available.
Grand Trunk Ry.....	12	3300 AC	P&F	"	3,913,300	None available.
Nor. & Western Ry..	90	11000 AC	F	"	56,651,700	Coal cheaper.
New York Central....	253	650 DC	P	"	102,585,000	None available.
N. Y., N. H. & H. R. R.	530	11000 AC	P&F	"	90,500,000	Some water pr.
M. C. R. R., Detroit..	25	650 DC	P	"	7,431,000	None available.
Hoosac Tunnel.......	21	11000 AC	P&F	Both	7,727,000	
B. & O., Baltimore...	8	650 DC	P&F	Water	6,200,230	
C., M. & St. P. R. R.	600	3000 DC	P&F	"	124,600,000	
B., A. & Pacific......	90	2400 DC	F	"	23,408,270	
Erie (Roch. Div.)....	38	11000 AC	P	"	1,894,860	
Great Northern......	10	6600 AC	P&F	"	4,080,000	
Southern Pacific......	114	1200 DC	P	Coal	30,082,000	
Total	2341				677,000,000	

GENERAL.—The development of any water power for a certain kilowattage should require that the combination of stream flow and reservoir capacity is capable of developing the same kilowattage throughout the year.

In the Middle Atlantic and New England States, within a reasonable distance—not to exceed 200 miles of any railroad having a dense traffic and excluding Niagara Falls—the streams where an appreciable head is available are erratic as to stream flow. A small amount of power can be developed economically, but to develop an amount reasonably to be expected from a central station requires either a reservoir or an auxiliary steam station. The result of this is usually a plant in which the capitalization is so excessive that, in spite of the low operating cost, electrical energy cannot be produced at a price to compete with that generated in an all-steam station of like capacity, and economy.

PENNSYLVANIA RAILROAD.—Of all the streams in the territory, the Susquehanna River is most favorable for water power development along the Pennsylvania Railroad, not only because the horsepower available for development is the highest, but because the river basin has the greatest drainage area and is the least settled, and places can be found for the power development site where the necessary land and rights can probably be obtained more cheaply than on any other river.

Examination of the records of the United States Geological Survey for the period from January 1, 1891, to December 31, 1908, shows that for the neighborhood of McCalls Ferry power plant, the minimum stream flow for the years 1901 and 1903 could have developed in one plant 28,000 K.W. In 1905 it could have developed approximately 40,000 K.W.; and in all other years only a little better than 10,000 K.W. This minimum stream flow occurred consistently in September and October. The maximum stream flow each year, during this period, could have developed in one plant an average of approximately 90,000 K.W. over any reasonable period.

At the McCalls Ferry plant it was proposed in 1916 to install 100,000 H.P. or 74,600 K.W. at an estimated cost, including transmission lines, of $12,600,000, or approximately $169 per K.W. of maximum utility. As the average utility, with reasonable pondage development, and without an auxiliary steam station would be much below the 74,600 K.W., the capital investment per K.W. useful throughout the year would have greatly exceeded $169. As the plant went into the hands of a receiver for lack of funds when only 60 per cent. of the project was completed, it is reasonable to assume that the company found the cost of the development of the property considerably in excess of the amount that they had estimated.

NORFOLK & WESTERN RAILWAY.—Water power was available from the Appalachian Power Company at a price of 0.83 cents per K.W.H. for an estimated annual consumption of 66,000,000 K.W.H. It was estimated that power could be produced in a steam station, with coal at $1.00 per

ton, and a power house near the mine, at 0.52 cents, including fixed charges. The engineers report as follows:

"Our estimates for the cost of power generated in the railway company's plant have shown by actual experience to have been very conservative. In 1916, when cheap coal was still obtainable, we generated power at 0.242 cents per K.W.H., or at 0.463 cents including fixed charges; these figures were obtained, moreover, on a yearly output of only 50,410,000 K.W.H. instead of 66,000,000. In 1918 (first three months), with coal at $2.50 per ton, we generated power at 0.418 cents per K.W.H., or including fixed charges at 0.596 cents. In this case our yearly output is at the rate of about 90,000,000 K.W.H. It is important to note that with the price of coal even doubled, our Bluestone plant is producing power at a very much lower cost than we would have paid had we tied ourselves up to a contract with the Appalachian Company."

It should be noted in this connection that the Appalachian Company have during the year 1918 increased all their power rates 25 per cent. The Norfolk & Western has a connection between its power transmission lines and those of the Appalachian Power Company, but so far it has aided the Power Company with current to greater extent than it has received aid.

The Baltimore & Ohio Railroad at Baltimore secures its power for operating 8 miles of its tracks under contract from the Consolidated Gas & Electric Company. The consumption of current therefrom in 1917 amounted to 6,200,230 K.W. hours. The Power Company during that year furnished this current from their Susquehanna River water power plant at 0.85 cents per K.W.H. In 1918 the Government required this power, and that furnished the B. & O. was taken from the steam power plant of the Consolidated Gas & Electric Company, located at Baltimore (Westport), and owing to increased cost of fuel the cost of current furnished in 1918 has been 1.2 cents per K.W.H.

The New York, New Haven & Hartford Railroad secures all its current for electric operation from steam power plants. The Committee is informed that in 1916 power from the Housatonic River, in the amount of 50,000,000 K.W.H. per year, was offered to the railroad, to be delivered at the contact wires at 0.68 cents per K.W.H., which figure is from 50 per cent. to 100 per cent. less than the corresponding amount of current being secured from steam plants during 1918. The limitations upon this current and of the value of the guarantee of the Power Company are not given. Evidently there was a mutual value in emergency situations secured by establishing a connection between the two transmission lines.

A former member of this Committee has contributed the following data as to an investigation for a suggested railroad electrification, based upon prices prevailing directly before the war:

"*General Proposition.*—Power was required for 100 miles division of a railroad which had better than the average density of passenger and freight traffic in the eastern section of the country. The proposition was to compare the cost of steam-generated electric versus hydro-electric power. In the case of the steam power, it was assumed that the railroad

company would build and operate the plant; for hydro-electric, that it would purchase the power delivered at a central point on the road, the power company building and maintaining a duplicate transmission line about 60 miles long.

"*Power Requirements.*—It was assumed that the maximum load at point of delivery would be 50,000 K.W. and that the load factor would be guaranteed at 35 per cent. of the maximum demand, requiring a dense traffic and care in regulating the train dispatching.

"*First Cost.*—The first cost of a steam power plant built by the railroad worked out at $3,300,000. This cost would produce a suitable, modern and economical turbo-generator plant having sufficient reserve capacity to carry the 50,000 K.W. at peak load and with spare plant for emergencies.

"In the case of the hydro-electric development there would be no cost to the railroad company for the power plant; but the fixed charges on the cost of a suitable plant, plus profit, is reflected in the charge made for power.

"*Power Costs.*—(a) Steam Plant. Good steam coal, having at least 13,000 B.T.U. value, would cost, delivered at the plant, $2.60 per gross ton. Fixed charges were as follows:

"Interest 5%, insurance 2%, depreciation 4%, total 11% on the cost of the plant.

"On the above basis, the cost of power delivered in substations worked out to be 0.683 cents per K.W. hour.

"(b) Hydro-electric power. The price named by the hydro-electric company for power delivered at the railway company's substation was 0.675 cents per K.W. hour. This price was on the basis of a certain guaranteed load factor and other conditions regarding growth of power requirements, as is usual in purchased power agreements.

"On the basis of the estimated yearly consumption of power (172,000,000 K.W. hours) the two propositions worked out as follows:

For steam-generated power ....$1,174,000 per year
For hydro-electric power .... 1,161,500 per year

"*Factors of the Problem.*—Aside from the relative cost of these propositions, there are, of course, other factors to be considered, as follows:

"1. *Reliability.*—In the case of the hydro-electric proposition, the traction project is dependent upon continuity of service over a long transmission line, whereas the steam-generating station would be located on the line of the road. Assuming equal reliability of generation, the steam power plant has advantage over the hydro-electric as regards reliability.

"2. *Location.*—As regards traction requirements. As the hydro-electric proposition is tied up to an inflexible location of plant, any change in the center of distribution would affect the length of the transmission line, and therefore may affect unfavorably the future development of the traction plan. In case of the steam power plant, this can be located with reference to future extensions of the traction scheme.

"3. *Output.*—Hydro-electric plants have a well-defined maximum output, depending upon the water supply; moreover, to make such a development pay, it is necessary to provide for the immediate sale of the entire peak output. This fact often prevents the Railroad Company from calling for more power as business increases.

"4. The flow of all streams is affected by great seasonal variations in volume. This means that the actual power that can be developed by

the flow varies greatly by seasons of a year, and again by years, some being dry and others rainy. To provide against the consequence of this variation, the scheme of empounding water can be adopted to a limited extent. Therefore it is customary to empound as much water as possible, and supply any deficiency in power during the dry season from an auxiliary steam power plant. When this steam power is drawn on, the cost of producing power will be increased."

The Committee calls attention to the following facts and statements of record:

Direct Saving of Fuel by Electric Operation.—A concrete example of fuel saving by the substitution of electric for steam operation where comparable statistics are available is the electrification of the Chicago, Milwaukee & St. Paul Railroad between Avery, Idaho, and Harlowton, Montana, a distance of 440 miles and comprising an electrification of 600 miles of track. During 1917, 124,000,000 K.W.H. (equivalent to approximately 3,900,000,000 ton miles) were generated by water power for the operation of trains. Based upon actual records taken prior to electrification, 220,000 tons of coal and 453,000 barrels of oil (equivalent to a total of 350,000 tons of coal) were burned under locomotives for an equivalent steam service. In 1917 there were 2365 miles of steam railroad under electric operation in the United States and it has been reported to the Committee that during the year there were 675,000,000 K.W.H. generated for the operation of trains over these electrified tracks. Applying the figures obtained from steam and electric operation of the Chicago, Milwaukee & St. Paul Railroad to all of the roads electrified, would result in a saving of 1,890,000 tons of coal per annum, had it been possible to produce all of this electrical energy by water power.

A concrete example of fuel saving, where coal is used to generate electric power, is furnished by the Norfolk & Western electrification of about 90 miles of track between Bluefield and Vivian. During the year 1917 there was generated 56,652,000 K.W.H. for the operation of trains, using 87,160 tons of coal at the power house. Based upon records of coal consumption on steam locomotives on the Norfolk & Western, 147,600 tons of coal would be required for an equivalent steam service. Applying a similar saving to the 2365 miles of electrified steam railroads would show a saving of 720,000 tons of coal per annum if all electric energy had been generated by steam power plants.

Amount of Water Power Available.—The total developed water power of the United States is reported by the Secretary of Agriculture in 1916 as 6,500,000 H.P. The undeveloped water power is reported in Senate Document 316, dated 1916, as 53,900,000 H.P., of which 39,200,000 H.P. is within the limits of the Rocky Mountains and Pacific Coast States.

Calvert Townley in a statement to a committee of the United States Chamber of Commerce, January 14, 1918, made in behalf of the Engineering Council (see Proc. A. S. C. E. and Sci. Amer. Suppl., April 27, 1918), calls attention to the fact that the federal government still

retains as proprietor more than two-thirds of the total area of the 13 Western States in which the bulk of the undeveloped water power is located. If any parts of the public lands are needed for reservoirs, dams, transmission lines, etc., a permit of the Secretary of the Interior is required, which is revocable at any time, without cause. Other water powers are on navigable streams, and require an Act of Congress for their development. A revision of these laws is under consideration. Outside of the western water power states and the territory tributary to Niagara, water power generally should be developed with auxiliary steam power.

H. S. Putnam presented a paper on Economical Combination of Water Power and Steam Plants at the American Institute of Electrical Engineers, June 28, 1917. The conclusions reached were that practically all water power plants should be developed beyond the minimum power available, and hence in combination with a steam plant. The economic limit depends on the value of money, fuel and labor, the increasing size and efficiency of steam turbines, and location of the enterprise.

C. P. Steinmetz, in an article on America's Energy Supply in Proc. Amer. Inst. Electrical Engineers, June, 1918, says that the economical utilization of the country's energy supply requires generating electric power wherever hydraulic or fuel energy is available and collecting the power electrically, just as we distribute it electrically.

Conclusions of the Committee on Water Power.

(1) It is important to reduce the use of coal where possible by the development of water power.

(2) Water power will show the greatest economy in the West on account of the higher cost of coal and minimum cost of water power development, but may show economy in other districts at present or future coal prices.

(3) In general, auxiliary steam plants should be built, to develop the water power beyond its minimum capacity, and to secure reliability of service.

(4) Laws should be modified to permit the development of water power on public lands and on navigable streams, under reasonable restrictions.

(5) In their studies and investigations of this subject the Committee have been impressed with the failure of some of the carriers to so keep their records as to permit the proper segregation of data which is necessary to calculate the tons of coal consumed in steam locomotives separated from coal consumed for other purposes on sections or divisions where electricity has been substituted for steam.

(ITEM 5) ELECTRICAL INTERFERENCE.

SUB-COMMITTEE No. 7.

A. H. Armstrong, Chairman;
Z. M. Briggs,
R. H. Ford,
H. K. Lowry,
W. S. Murray,
J. R. Savage,
M. Schreiber,
A. G. Shaver.

This Sub-Committee was charged to report "recommended practice for eliminating, so far as practicable, interference with telephone and telegraph lines caused by the use of propulsion circuits." Owing to the fact that other engineering associations and several manufacturing companies have the matter of electrical interference under very careful consideration, it is thought best to limit the report at this time to a brief statement of some of the factors involved in electrical interference, as general information for this Association.

The interference with adjacent telephone and telegraph lines by railway propulsion and signal currents may be divided into two broad classes as follows:

(1) *Interference by Direct Currents.*—The oscillograph has shown that direct currents, produced by commutating machines, are made up of a series of minute waves or ripples, which under certain conditions on long parallel lines of higher voltages may produce a high frequency disturbance in neighboring telephone circuits of sufficient magnitude to constitute an interference. It is known that these "ripples" may be minimized by machine design and it is suggested that manufacturers of commutating machines should exercise care in this direction and agree upon some standard test for the higher voltage machines, which must be passed in order to be accepted for railway service. It is also suggested that the telephone and telegraph companies define some maximum degree of noise interference expressed in terms which will permit accurate duplication in test under different conditions.

It is admitted that such interference with telephone lines caused by direct railway currents from commutating machines already in service can be practically eliminated at a small expense by the installation of resonant shunts in the power house or sub-station.

Direct currents carried over railway circuits having rail and grounded return may in some cases interfere with the operation of single wire telegraph and signal circuits using grounded return. Such troubles may be minimized by adequate bonding of the rail circuit and periodic inspection to eliminate faulty bonds.

(2) *Interference by Alternating Currents.*—The interference by alternating railway propulsion and signal currents with adjacent telephone and telegraph circuits is more serious than from direct current and the correction thereof is more difficult.

The Committee is of the opinion that practice in this matter is not yet sufficiently standardized to justify a report to the Association at this time. Reference is made to the very instructive paper by H. S. Warren, read before the Franklin Institute in Philadelphia.

Proposed National Electrical Safety Code.

In accordance with the action of the Association at its meeting held in March, 1918, under date of August 13, a copy of last year's report containing the Committee's criticisms of the National Electrical Safety Code was sent to Dr. E. B. Rosa, Chief Physicist, Bureau of Standards, Department of Commerce, Washington, D. C., and advising him that should he desire a conference with the representatives of this Committee, that delegates would be sent at his convenience. The Director of the Bureau of Standards under date of August 14th wrote: "We do not feel that it is necessary for your Committee to send delegates to the Bureau at the present time, but we shall be glad to send to the members of your Committee copies of the tentative revised draft of part 2 for your consideration and criticism and to yourself revised drafts of all other parts of the Code. We should be glad to have individual criticisms of this draft and also any additional suggestions which they might care to make. After considering the revised draft if your Committee feels that a personal conference would be desirable, or if we find that such a discussion seems desirable on our part, we shall be glad to arrange for a conference with the delegates of your Committee." The revision of part 2 has not yet been issued. A tentative draft of part 3 of the Code has been received and comments thereon were submitted to the Bureau of Standards under date of October 22, 1918. Representatives of the Committee, at the invitation of the Director of the Bureau of Standards, attended a conference in Washington on January 16, 1919, and a proposed revision of part 2 was discussed at some length, but no action had been taken on the previous suggestions made by the Committee. Dr. Rosa informed the delegates that copies of the revised part 2 would shortly be issued and criticisms invited. Further effort on the part of your Committee must, therefore, be deferred. The following are the delegates representing the Association in this matter: E. B. Katte, H. M. Bassett, R. D. Coombs, J. R. Savage.

(ITEM 6) AMERICAN COMMITTEE ON ELECTROLYSIS.

No meeting of the American Committee on Electrolysis has been held since the beginning of the war, and there are no indications of a meeting being held in the near future. The following have been designated to represent the Association on this Committee: E. B. Katte, D. J. Brumley, C. S. Churchill.

(ITEM 6 CON.) NATIONAL JOINT COMMITTEE ON OVERHEAD AND UNDERGROUND LINE CONSTRUCTION.

There has been no meeting of this committee since July 16, 1915, and the work has virtually been absorbed by the United States Bureau of Standards, as reflected in the wire crossing requirements of the National Safety Code. Representation may, therefore, be dropped from the subjects assigned to this Committee.

RECOMMENDATIONS.

The Committee on Electricity recommend the following for your action:

(1) The adoption and publication in the Proceedings and in the Manual of the electrical definitions listed in the report of Sub-Committee No. 1, and continue the examination of the subject-matter in the Manual pertaining to Electricity.

(2) Continue collecting statistical data relative to Clearances of Third Rail and Overhead Working Conductors, and submit revised tables at the next annual meeting.

(3) Continue the subject of the revision of joint specifications for transmission line crossings over railroad companies' right-of-way and send delegates to co-operate with committees of the American Railroad Association and of the American Electric Railway Engineering Association and the United States Bureau of Standards.

(4) Continue the subject of Electrolysis and Insulation and send delegates to co-operate with the American Committee on Electrolysis in the preparation of its future report.

(5) Continue the subject of Maintenance Organization and relation to track structures.

(6) Accept as information and publish in the Proceedings the report of Sub-Committee No. 6 on Water Power. In this connection the Committee desires to call attention to the fact that it has found but little data bearing on the cost of steam railroad operation applicable to divisions where electric operation has been established, and urge upon engineers and accounting officials the desirability of so arranging the accounts as to accurately show the cost of steam operation and that such accounts be available before attempting to compute the cost of electric operation.

(7) Accept as information and publish in the Proceedings the report of Sub-Committee No. 7, on Electrical Interference, and continue the subject.

(8) Accept as information and publish in the Proceedings the Committee's report on the National Electrical Safety Code, and continue co-operation with the United States Bureau of Standards in the preparation of Safety Codes.

(9) The acceptance and publication in the Proceedings of the report as a whole.

Respectfully submitted for the Committee,

EDWIN B. KATTE,
Chairman.

REPORT OF COMMITTEE VI—ON BUILDINGS.

M. A. Long, *Chairman;*
G. H. Gilbert, *Vice-Chairman;*
G. W. Andrews,
E. A. Harrison,
D. R. Collin,
A. Larsen,
W. H. Cookman,
J. W. Orrock,
C. G. Delo,
S. B. Phillips,
W. T. Dorrance,
R. V. Reamer,
K. B. Duncan,
C. W. Richey,
C. H. Fake,
John Schofield,
A. T. Hawk,
Z. H. Sikes,
F. F. Harrington,
W. J. Watson,

Committee.

To the American Railway Engineering Association:

Your Committee on Buildings submits herewith its report to the Twentieth Annual Convention.

The following subjects were assigned the Committee by the Board of Direction:

1. Make critical examination of the subject-matter in the Manual and submit definite recommendations for changes, with especial reference to appropriate definitions.
2. Report on coaling stations.
3. Report on freight-house and passenger station scales.
4. Report on ash pits.
5. Report on a classification of buildings on the basis of "Specification Types," and upon the use of the "cubic foot," "square foot" and "bill of particulars" methods for ascertaining the approximate cost of new construction.
6. Report on detail designs of buildings used for housing track labor, conferring with Committee on Economics of Railway Labor.
7. Report on the efficient and economical methods of electric lighting of (a) Passenger station interiors.
   (b) Passenger station surroundings.
   (c) Platforms covered and uncovered.
8. Report on modern types of toilet facilities at small stations where water supply and sewers are lacking.

Your Committee recommends the following action be taken on its report:

1. That the matter under "Revision of Manual" be approved.
2. That the conclusions under the heading of "Design and merits of high and low platforms at passenger stations" be approved and published in the Manual.
3. That the conclusions under the heading "Umbrella versus Butterfly sheds" be approved and published in the Manual.

RECOMMENDATIONS FOR FUTURE WORK.

Your Committee recommends that the same subjects be reassigned for the coming year.

Respectfully submitted,

Committee on Buildings.

Appendix A.

REVISION OF MANUAL.

Definition of Terms Published in the Manual and Supplements Thereto.

STATION.—An established location for the accommodation of passenger and freight traffic. (Manual 1915, page 187.)

TRANSFER PLATFORM (FREIGHT).—A platform approximately level with freight car floors used in transferring freight from car to car. (Manual 1915, page 207.)

SHOP BUILDINGS.—Various structures for the construction and repair of locomotives, cars and other railway equipment. (Manual 1915, page 188.)

ENGINE HOUSE.—A structure for housing and the general maintenance of engines in service. (Manual 1915, page 188.)

TURNTABLE.—A revolving structure for turning locomotives or cars. (Manual 1915, page 188.)

TRANSFER TABLE.—A traveling structure with a track on which a locomotive or car can be run and transferred from one parallel track to another. (Manual 1915, page 188.)

COALING STATION.—An established location for the storing and delivering of coal to locomotives. (Manual 1915, page 192.)

OIL HOUSE.—A building for the storage and distribution of oil and waste. (Manual 1915, page 194.)

SECTION TOOL HOUSE.—A building for housing of section cars, tools and small track material. (Manual 1915, page 195.)

POWER HOUSE.—A building for housing apparatus for supplying light, heat and power for various purposes. (Manual 1915, page 189.)

REST HOUSE.—A building for the accommodation of employees, usually containing rest and recreation rooms, sleeping quarters, lunch room, lockers, baths, etc. (Manual 1915, page 208.)

BUTTERFLY SHED.—A type of structure erected over platforms for protection from the weather with a central line of supports and roof sloped towards center for drainage. (Manual 1915, page 208.)

UMBRELLA SHED.—A type of structure erected over platforms for protection from the weather with a central line of supports and roof sloped to the sides for drainage.

ASH PITS.—A structure into which cinders are deposited from locomotives, for subsequent removal. (Supplement to Manual 1917, page 35.)

INBOUND FREIGHT HOUSE.—A building for the handling of freight for delivery to consignee. (Manual 1915, page 201.)

OUTBOUND FREIGHT HOUSE.—A building for the receiving of freight by the railroad for shipment. (Manual 1915, page 201.)

Following Additions to the Manual.

Coaling Stations.

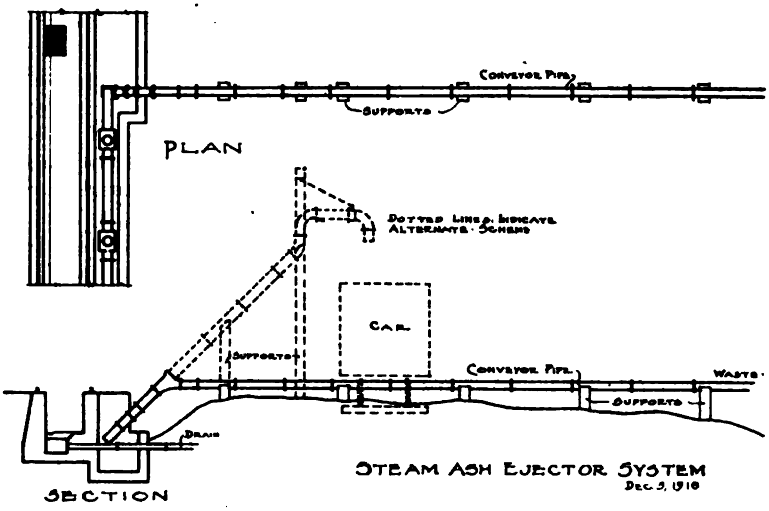
Where coal is stored in summer for use in locomotive stations in winter and where the amount stored is less than 75,000 tons, no special mechanical device is recommended, it being more economical to store it by unloading cars by hand or crane and reclaiming it by the use of tools that can be put to other use when not handling coal, such as locomotive crane, ditcher or steam shovel.

The question of storing coal is covered in the Proceedings of the International Fuel Association of 1917.

Ash Pits.

We wish to add an additional cut and description as follows.

A scheme for conveying and disposing of cinders through pipe by vacuum created by steam. In order to handle them by this method cinders must not be wet down.



Scales.

At terminal stations where scales can be given proper attention and where the volume of business will justify, dial scales are preferred for weighing mail, baggage and express.

Appendix B.

REPORT ON DESIGN AND MERITS OF HIGH AND LOW PLATFORMS AT PASSENGER STATIONS.

While very few railroads in this country have adotped platforms level with the car floors, they have always been the standard in use in Great Britain.

One of the chief recommendations for raised platforms is the saving of time required for passengers boarding and leaving cars over that required for walking up and down steps at low platforms.

As the interchange of equipment is extensive, clearance must be provided for the widest equipment on the roads involved.

As passenger equipment is narrower than freight equipment, this arrangement leaves a void or space between the car and platform that might cause accidents to passengers who carelessly enter and leave trains. Some railroads are equipping their passenger cars with an extension flap to the trap door to bridge this opening; the operation of it is practically automatic. When the trap door is down the opening of the vestibule door causes the sliding portion to extend beyond the side of the car. Closing the door returns it to its normal position.

When it is necessary to raise the trap at stations not equipped with high platforms it is not desirable for the trap to be extended. To provide for this feature a handle is set flush in the end of the car body by means of which a connection between the door and the trap may be disengaged. It is designed with a uniform extension to take care of a gap at platforms built on curves as sharp as 6 degrees.

There are platforms in use in subways that have mechanical extensions moving out until they are practically touching the side of the car, so that there is practically no space between the side of the car and the platform.

Platforms are built either of wood, concrete or steel, or a combination of these materials. At important points, where traffic is heavy, they should be roofed over.

Where high platforms are used it is necessary to use a special design of baggage truck. One road having in use a great many high platforms is considering the construction of trucks on small wheels on which the baggage will be stored until the arrival of the train, the truck will then be pushed into the baggage car and left there with its load to be assorted while the train is traveling from one station to another. The baggage to be taken off at the next station will be loaded on this or a similar truck, so that an entire load can be taken out of the car as soon as the train stops. In this scheme the time consumed for handling baggage, express and mail at stations will be reduced considerably.

Low platforms are more universally used and consist of cinder fill, with or without wood or concrete curbs, brick with concrete curb, concrete with concrete curb, and concrete with a wearing surface of asphalt mastic.

In comparing high platforms with low platforms, the advantages in favor of the high platforms are as follows:

1st—Facility, rapidity and safety with which trains may be loaded or unloaded.

2nd—The prevention of the public crossing the tracks.

3rd—Where platforms are below the street level, a saving of about 3 feet in the vertical height to be traveled by passengers.

4th—Passenger, baggage, express and mail can be handled more rapidly, which means a reduction in the time of station stops.

5th—They afford convenient space for the housing of ducts, cables, signal equipment and sometimes elevator machinery.

6th—Where passenger traffic is heavy raised platforms permit the use of additional doors.

They have certain disadvantages:

1st—The cost of changing passenger equipment to serve both high and low platforms, and the cost of constructing subways or bridges for passengers, express and baggage.

2nd—Where freight trains must use the tracks adjacent to high platforms the restricted clearances may prevent the operation of certain cars and cause heavy expense for transfer of freight.

3rd—The necessity for special form of baggage truck having a low floor.

4th—It is impractical to place a switch within the limits of the platform, due to lack of clearance for equipment.

By canvass of various roads it is found that low platforms vary from 5 ft. to 5 ft. 6 in. from the center of track to the face of platform curb, and level with the top of rail to 6 in. above it.

It is recommended that low platforms be built to 5 ft. 6 in. from center of track to face of curb and to be 4 in. above top of rail at curb.

Fig. 1 shows the high platform referred to in this report and also shows an Umbrella Shed and Butterfly Shed with respect to the clearance diagram of this Association and shows the clearances in use on various railroads at this time. (English maximum.)

Recommendations for the Manual.

On account of the existence of high platforms at important terminal stations and the desirability of interchange of passenger equipment throughout the country, the Committee suggests that the Association recommend to the M. C. B. Association that all passenger equipment in the future be so constructed that they can be used at either high or low platforms.

It is recommended that high platforms be provided only in connection with tracks devoted exclusively to passenger business.

Appendix C.

REPORT ON COMPARISON OF "UMBRELLA" VERSUS "BUTTERFLY" SHEDS AT THROUGH STATIONS.

There is no choice between the Umbrella shed and the Butterfly shed, so far as protection from the elements is concerned, the edge of the gutter being in the same relative position on both types. Neither one successfully accomplishes what they are designed for, as the edge of the roof must be kept outside of the clearance diagram, and this places the protective feature so far from the coaches that the benefit to passengers is limited.

Where no waiting room is provided in connection with Umbrella sheds, it is recommended that partitions be built between supporting columns; these partitions to be located at every third bay where traffic is heavy, and every fifth bay where traffic is light.

With the Umbrella shed type, two gutters and two leaders from the gutters to the central post are necessary. With the Butterfly type no gutters are required. This eliminates the first cost for gutters and means lower maintenance cost on account of the lack of same.

Some railroads use circular supporting columns for butterfly type, making use of this column for the regular down-spout. On account of the prevalence of cinders the drains at the bottom of the columns are likely to be stopped up, and in cold weather the columns will freeze and burst.

In either type of shed it is recommended that at or below the platform level of the down spouts a trap with clean-out be installed.

It is considered preferable to place the down-spouts outside the supporting column.

At Umbrella sheds in some parts of the country snow collects in such quantity that it becomes necessary to shovel it off. Consideration should be given roofing sheds in such localities, with a roof having a hard surface, as a composition roof is easily ruined by laborers digging into it with picks and shovels removing snow and ice.

The cut shown in connection with report on "Merits of High and Low Platforms at Through Stations," also shows in outline Umbrella and Butterfly sheds.

A canvass of the representative roads shows that the cost of Umbrella and Butterfly sheds is very similar, an average pre-war cost being $1.10 per sq. ft., exclusive of the paving and curb.

The average height from curb to eaves is 16 ft. The average spacing center to center of supports is 30 ft.

The above average price covers the cost of various types of sheds, including the following:

(1) Steel supporting structure covered with wood sheathing and composition roofing.

(2) Frame supporting structure covered with wood sheathing and composition roofing.

(3) Pre-cast concrete columns and roof slab covered with composition roofing.

Conclusions.

In that part of the country where heavy snow occurs Umbrella type of shed is preferable, though somewhat more expensive in first cost.

In that part of the country where heavy snows are not a factor, the Butterfly type of shed is preferable.

PROGRESS REPORT OF SPECIAL COMMITTEE ON STRESSES IN TRACK.

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CHAS. S. CHURCHILL,
ALBERT REICHMANN,
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ROBT. W. HUNT,
J. E. WILLOUGHBY,
J. B. JENKINS,
Committee.

To the American Railway Engineering Association:

The Special Committee on Stresses in Track, co-operating with a similar committee of the American Society of Civil Engineers, presents the following report of progress:

The conditions incident to the war have greatly interfered with the progress of the work of the Committee. Early in the year the call to government service took away the last of the technical assistants who had become trained in this very special work. Some temporary assistance was used during the summer and fall, and it is hoped now that a small technical staff may be again developed. As the work is very special it is not easy to get the right help even in peace times.

During the year the data of the tests to find the effect of counterweight of locomotive drivers made late in 1917 on the track of the St. Louis-San Francisco Railway have been worked upon with very interesting results. Tests were also made on the track of the Illinois Central Railroad to find the effect of counterbalance of the Mikado locomotive. Other tests were made on the Illinois Central Railroad and the Chicago, Milwaukee & St. Paul Railroad to determine the distribution of pressure immediately under the tie and also the stresses in the tie, and considerable work has been done in reducing the data.

The Committee plans to study the results of the experimental data now available and to take up the preparation of a report upon the part of the subject so covered. It is believed, too, that sufficient information has now been accumulated to begin the discussion of the relation of the results to the principles governing the design of railroad track. It is expected also that the test work will be continued during the coming year.

As the Progress Report of the Committee last year reached the membership only shortly before the annual convention, there was little opportunity for its discussion at the convention. After considering the report, members of the Association may now desire to present discussions upon it. The Committee will welcome questions, comments and discussions. Any suggestions as to further work in connection with the field of the Committee will be gladly received.

Respectfully submitted,

THE SPECIAL COMMITTEE ON STRESSES IN TRACK.

REPORT OF COMMITTEE XX—ON UNIFORM GENERAL CONTRACT FORMS.

E. H. LEE, *Chairman;*
C. FRANK ALLEN,
O. P. CHAMBERLAIN,
A. O. CUNNINGHAM,
THOS. EARLE,
W. D. FAUCETTE,
G. E. GIFFORD,
C. A. WILSON, *Vice-Chairman;*
J. C. IRWIN,
R. G. KENLY,
A. S. KENT,
H. A. PALMER,
C. J. PARKER,
Committee.

To the American Railway Engineering Association:

Your Committee on Uniform General Contract Forms begs to submit the following report:

The Committee, as its work for the year 1918, received the following instructions:

(1) Make critical examination of the subject-matter in the Manual, and submit definite recommendations for changes.

(2) Report on Form of Agreement for Railway Crossings.

(3) Report on Form of Agreement, embodying rules governing the construction of under-crossings of railways with electrical conductors, conduits, pipe lines and drains, conferring with Committee on Roadway and Committee on Electricity.

(4) Report on Form of Lease Agreement for Industrial Site.

(1) REVISION OF SUBJECT-MATTER IN THE MANUAL.

The Committee has no recommendation as to changes in the subject-matter now in the Manual under the heading "Uniform General Contract Forms."

(2) REPORT ON FORM OF AGREEMENT FOR RAILWAY CROSSING.

Your Committee considered this form of agreement at several meetings. The Form of Agreement for Railway Grade Crossings herewith submitted is the result of action taken at these various meetings. No attempt has been made to specify a basis upon which the expense for construction, maintenance and operation shall be divided. In this respect the submitted Form of Agreement conforms with the Form of Agreement for Interlocking Plant, submitted by this Committee and approved by the Association at the last annual meeting. Similarly while articles covering liability and arbitration are incorporated in the submitted form in order to complete the same, it is recognized that these two articles will doubtless be modified in many cases to meet local conditions and the views of various legal departments of railroads.

Conditions differ widely in different portions of the country. In the older portions it is to be presumed that relatively few railway grade cross-

ings will be constructed, without the immediate installation of interlocking protection, whereas in many newer portions of the country railway grade crossings are still being constructed without such protection.

It will be noted that seniority as between companies has been given no specific recognition in the submitted form. The Committee has assumed that seniority will be given due weight in concluding the bargain which will be made in each case. The Committee further assumes that in general the senior company will prefer to retain the actual work of constructing, maintaining and operating the grade crossing in its own hands.

(3) REPORT ON FORM OF AGREEMENT EMBODYING RULES GOVERNING THE CONSTRUCTION OF UNDERCROSSINGS OF RAILWAYS WITH ELECTRICAL CONDUCTORS, CONDUITS, PIPE LINES AND DRAINS;

and

(4) REPORT ON FORM OF LEASE AGREEMENT FOR INDUSTRIAL SITE.

Your Committee wishes to report progress on these forms and to recommend that these subjects be reassigned for future consideration.

Respectfully submitted,

COMMITTEE ON UNIFORM GENERAL CONTRACT FORMS.

Appendix A.

AGREEMENT FOR GRADE CROSSING.

THIS AGREEMENT, made this..........day of.................,
in the year............, by and between..............................,
party of the first part, hereinafter called.............................,
and..., party of the second
part, hereinafter called....................................

(Note.—During Federal control terminology should conform to requirements of Federal Administration.)

Historical.

WHEREAS, ...
....
....
....
....

(Note.—Include brief description of conditions, including the location of existing or proposed grade crossing, an enumeration of all existing agreements, if any, the name of the companies between which agreements are made, their dates, their purpose, et cetera.)

WHEREAS,...............................desires the right to construct, maintain, use and operate a grade crossing across the tracks and right-of-way of.................................to permit the passage of its trains over and across the right-of-way and tracks of.............
...........................and........................is willing to grant said right; the location of said crossing and its proposed arrangement being shown upon a blueprint marked "Exhibit A," dated...........
.................................., identified by the signature of the
.... of ....
and of.............................of.............................
hereto attached and hereby made a part of this agreement; and

WHEREAS, The parties hereto have agreed upon the terms and conditions upon which said crossing as shown upon said "Exhibit A" shall be constructed, maintained and operated.

NOW, THEREFORE, In consideration of the premises and in further consideration of the mutual covenants and agreements hereinafter stipulated to be kept and performed, it is mutually agreed between the parties hereto, for the purpose of defining the terms and conditions upon which said crossing shall be constructed, maintained, renewed and operated, as follows:

Definition.

1. The term crossing as herein contained shall include rail, crossing frogs, track fastenings, crossing timbers, and other track appliances, included between the outer joints of one or more crossings installed or hereafter installed; together with ballast, drainage, side ditches, sub-

drainage, and other substructure appliances, devices or supports on the right-of-way of..................................Company in so far as affected by said crossing; all necessary buildings, including flagmen's houses, shanties or towers; gates, semaphores and other safety devices or appliances; all as may be required to keep said crossing in safe and suitable condition for the operation of trains, as required by............... ....Company or by lawfully constituted public authority.

Grant.

2. ....hereby grants to.................. subject to the conditions and stipulations of this agreement, the right to construct, maintain, renew and operate at grade..........., track....... of the.......................................Railroad, over and across the right-of-way and tracks of............................ .... at the point of crossing, as shown on "Exhibit A."

Construction.

3. The.................................Company agrees to construct a grade crossing as shown upon said "Exhibit A" and according to detail plans and specifications, which have been approved by the......... ....Engineer of the............................... and identified by...signature. The said..Company agrees to begin the construction of said crossing within.... .... days after the execution of this agreement and to carry the same forward continuously to prompt completion.

Apportionment of Cost.

4. The cost of constructing, maintaining, renewing and operating said crossing shall be borne by the respective parties hereto as follows:
....
....
....

In the cost of maintaining and renewing said crossing shall be included the expense for taxes, assessments, and insurance; any losses by fire, floods and other damage caused by the elements; also any change made necessary by an act or ordinance of a lawfully constituted public authority, except as herein otherwise provided.

Extensions and Changes.

5. (a) The...............................Company reserves the right to construct, maintain, renew and operate upon its right-of-way from time to time such other additional track or tracks as it may deem necessary or desirable crossing the track or tracks of the............... ....Company, the right to construct which is herein granted, and all the provisions and stipulations herein contained shall apply to such other additional track or tracks.

(b) The....................................Company reserves the right to change the grade of its track or tracks as shown on said "Exhibit A" not to exceed................feet, and the grade of the crossing shall be changed to conform thereto. The expense of so changing shall be borne as follows:

....

....

....

(c) Either company shall have the right at its own expense to make minor changes in alinement at said crossing, provided that this shall not materially interfere with the tracks of the other party, but nothing herein contained shall be interpreted to cover major changes in grade or alinement, such as separation of grade or elevation of tracks required or brought about by laws or ordinances of properly constituted public authorities.

(d) Improvements or devices which may be necessary in order to conform to the standard practice of the........................Company shall be provided as required by that Company, and the expense shall be borne in accordance with the provisions of Section No. 4 hereof.

(e) The privileges hereinbefore granted are granted upon the further express condition that whenever anything may be done or may be required to be done by the Chief Engineer of.......................... Company, or under and in pursuance of any of the laws of the State of ...., or of any lawful action of proper public authorities in respect to the said crossing, including the installation of gates, signals or interlocking, the................................ Company shall make all changes at said crossing and in present or future tracks of both companies and their appliances, necessary to comply with or carry out the requirements of the Chief Engineer of the............. ....Company or of law, or action of such authorities, and the cost thereof shall be apportioned in accordance with Article 4 hereof.

(f) It is further understood and agreed that the.................. ....Company will pay the cost of any connecting or transfer track or tracks that may, at any time, be required at or near the point of the crossing aforesaid, whether such track or tracks be ordered by competent authority, or put in by agreement between the parties hereto. If the junction switches of the said connecting track or tracks in the main track or tracks of either of the parties hereto shall be or come to be within the limits of an existing interlocking plant, said junction switches shall be taken into the protection of said interlocking plant and the cost shall be borne as follows:

....

....

....

Maintenance and Renewal.

6. The crossing shall be maintained by the.......................... Company. In case.......................................Company shall remove its tracks or any of them at said crossing, the track or tracks of the..Company shall be restored by the.............................Company to their original condition, to the satisfaction of the Chief Engineer of the. ....Company, and at the sole cost and expense of the ....Company.

Control.

7. The maintenance, renewal, operation and protection of said crossing shall be under the sole charge and control of the................... ....Company, and it shall employ competent persons to maintain, renew and protect the same, and such parties from time to time so employed shall be removed for good and sufficient reason upon request in writing of a general managing officer of the.......................... ....Company.

Each of the parties hereto, through its authorized employes and representatives, shall have the right at all times to inspect said crossing, as well as the accounts covering the construction, maintenance, renewal and operation of the same; and in the event that the......................... Company shall notify the...................................Company in writing of renewals and repairs that may be necessary for the safe and proper operation of said crossing, and if the.......................... Company neglects for a period of thirty days to make said necessary renewals and repairs, then the.................................Company shall have the right to make such renewals and repairs, and the...... ... .Company shall, upon presentation of proper bills, and within the time provided in Section 11 hereof, pay its proportion of the amount so expended.

Protection.

8. During construction and thereafter, flagmen or signalmen shall be furnished for the proper protection of said crossing, and such persons from time to time so employed shall be removed for good and sufficient reasons, upon request in writing of a general managing officer of the .... Company. The expense for their wages, together with the cost of materials and supplies required in connection with their work, shall be apportioned as herein in Article 4 provided. Until interlocking protection shall have been provided, all trains shall approach said crossing under full control, and shall come to a full stop within...........feet from said crossing, and shall not proceed until the receipt of a proper signal so to do.

Precedence.

9. In the use of said crossing, passenger, mail and express trains shall have precedence over freight or work trains and light engines, and

freight or work trains shall have precedence over light engines. The trains and engines of the........................Company shall have precedence over the trains and engines of like class of the............. Company.

Ownership.

10. Each of the respective parties hereto shall participate in the ownership of the crossing in the proportion which the payments made by it for construction of same bear to the total cost of construction.

Payment of Bills.

11. The payment of all bills under this agreement shall be made not later than the twenty-fifth day of the month following the month in which said bills are rendered. The bills for expense of construction shall be made as a final bill, unless otherwise mutually agreed and understood.

Bills covering maintenance, renewals and operation, taxes and assessments shall show total expenditures, and proportions chargeable to each of the respective parties hereto, and shall be rendered monthly; those covering insurance, taxes and assessments annually.

Should any dispute arise as to the correctness of any of the items included in bills rendered, under this agreement, the party against which any such bill is rendered, shall pay as herein provided, an amount equal to the sum of all items in said bill, the correctness of which is unquestioned. The remainder, covering disputed items, shall be paid promptly as herein provided, upon an adjustment of the dispute.

Added Percentages.

12. In making bills for the cost and expense of constructing, renewing, maintaining, operating and protecting said crossing, all labor and material shall be charged for at actual cost, plus..............per cent. added to material, and..............per cent. to labor to cover freight charges or accruals, handling, superintendence, use of tools and accounting, except that work done by contract shall have no percentages added.

Such of said bills as are based upon payroll cost of labor and stock prices of material shall include a fair arbitrary charge to cover supervision, inspection, handling, transportation, accounting and similar undistributed items of expense. Such fair arbitrary charge shall be agreed to by the parties, or determined by arbitration as hereinafter provided.

The provision as to actual cost herein contained shall not be considered or held as a warrant for charging excessive prices or freight rates on material, for hauling the same unreasonable distances, nor for the payment of unreasonable arbitrary charges of any kind.

Liability.

13. Each party hereto assumes for itself the responsibility and risk of using and operating its own trains and engines over the space covered

by the said crossing, and also responsibility for the negligent acts and omissions or the alleged negligent acts or omissions of its own officers, agents, servants and employes engaged in connection therewith; and in performance of any of its separate duties under this contract; and will pay to the other party and to third persons all damages which may arise and for which it may be liable arising from such negligence and in such operation.

The party having special charge of the management and operation of said crossing shall not be liable to the other party for the negligent acts or the omissions, or the alleged negligent acts or omissions of any person employed in the operation, maintenance or repair of said crossing, but all persons so employed shall, as respects any injury caused by such negligence, be regarded and treated as the agents or servants of each party hereto, and each of said parties hereby assumes the responsibility for all damages resulting from the negligence of such agents or servants in the operation of its own engines, cars and trains, and those of its tenants, lessees and licensees, at the said crossing, and shall indemnify and save each of the other parties harmles therefrom. Any expense caused or growing out of the injury of any workman or employe engaged upon the construction of said crossing shall be held and considered to be a construction expense, and shall be divided as herein in Section 4 provided.

Arbitration.

14. In case of any differences or dispute arising under this agreement or concerning the subject-matter thereof, the parties hereto agree to submit such difference or dispute to three arbitrators, one of whom shall be appointed by the........................Company, and another by the ....Company, and each party shall give to the other party written notice of appointment of its arbitrator, together with his name and address. The two arbitrators so chosen shall select a third arbitrator. If either party shall fail to choose an arbitrator as herein provided, the arbitrator selected by the other party hereto, at the expiration of..........days after the date of its said written notice, shall select a second arbitrator, and the two arbitrators so chosen shall select a third arbitrator. If within..............days after the appointment of a second arbitrator, as herein provided, the two so chosen shall have failed to select a third arbitrator, either party hereto may apply to any judge of the District Court of the United States for the District which shall then include...
....
or who shall thereupon appoint the third arbitrator. The three arbitrators so chosen in any manner as herein provided, or a majority of them, shall hear and decide said difference or dispute, and their decision, or that of a majority of them, shall be final and binding on the parties hereto.

The expense of an arbitration under the terms hereof shall be borne by the parties hereto in the proportions fixed by the arbitrators.

Cancellation of Conflicting Agreements.

15. It is mutually understood and agreed that any and all agreements relative to said crossing, existing between the parties hereto or their predecessors, so far as they conflict, or are inconsistent with the terms and provisions of this agreement, are hereby annulled, but in all other respects they shall continue in full force and effect.

Duration and Succession.

16. This agreement shall remain in full force and effect as long as the tracks of the respective parties cross at grade at the location shown upon "Exhibit A."

The provisions of this agreement shall be binding upon and inure to the benefit of the parties hereto, their successors, lessees and assigns.

In Witness Whereof, the parties have caused these presents to be executed in duplicate by their respective officers as of the day and year first above written.

Attest:

....	..........................Company
Secretary.	By................................
	..........................(Title)

Attest:

....	..........................Company
Secretary.	By................................
	..........................(Title)

REPORT OF COMMITTEE III—ON TIES.

F. R. LAYNG, *Chairman;*
W. C. BAISINGER,
M. S. BLAIKLOCK,
F. T. BECKETT,
F. BOARDMAN,
W. J. BURTON,
W. A. CLARK,
S. B. CLEMENT,
H. S. WILGUS, *Vice-Chairman;*
E. L. CRUGAR,
L. A. DOWNS,
G. F. HAND,
E. D. JACKSON,
A. J. NEAFIE,
G. P. PALMER,
LOUIS YAGER,

Committee.

To the American Railway Engineering Association:

The following subjects were assigned your Committee by the Board of Direction:

1. Make critical examination of the subject-matter in the Manual, and submit definite recommendations for changes.
2. Continue the study of effect of design of tie plates and spikes on the durability of cross-ties.
3. Report on methods in use by various railways for controlling tie renewals.
4. Recommend proper dimensions for cross-ties.
5. Report results of investigation of Forms M. W. 301, 302, 303 and 304, Statistics of Cross-Ties, to see if they are in general use on membership lines.
6. Report on trials of substitute ties.

(1) REVISION OF MANUAL.

The Committee recommends that forms M. W. 301, 302, 303 and 304 be withdrawn from the Manual. The report of Sub-Committee (5) shows that these forms are not being used.

(2) EFFECT OF THE DESIGN OF TIE PLATES AND TRACK SPIKES ON THE DURABILITY OF CROSS-TIES.

In 1914, twenty-seven out of twenty-nine railroads who gave an opinion agreed on the statement "screw spikes prolong the life of ties over that obtained with cut spikes." Three years later a committee for the Pennsylvania Railroad finished an investigation on this subject, which it had conducted for nine years, and agreed upon the following statement: "Screw spikes have no advantage over nail spikes. When used with clips without tie plates, the cutting of the rail into the tie permits the rail to slip under the clip, thus widening the gage."

As a result of these diverging opinions, your Committee has tried to find the present general opinion among railroads on this subject, in the hope that they could summarize the practice and distinguish the conditions under which either form of track connection was the better as regards the durability of the ties.

For this purpose, the following list of questions was sent to 75 railroads. From these, 58 have replied, and of these 58, 52 stated either that they had never used any screw spikes, or else that their trials had been so limited that no conclusions could be formed. Of the other 6 replies, 2 railroads believed that screw spikes permitted a longer life of tie than cut spikes. Three railroads reported that screw spikes did not permit longer life of tie than cut spikes. One electric elevated and subway road reports that screw spikes do prolong the life of ties. Two railroads believed there was no reason for using screw spikes unless the ties were bored and treated before the screw spikes were applied. Six railroads considered this unnecessary. Eight railroads believed that a screw spike should not be used as an anchor, and that it should be kept free from the slots in the angle. Five railroads considered that it should be used as an anchor and put in the slots in the angle. One railroad used some device to put in the spike hole to make the screw spike secure again after it had become loose, or after the chamber around it had decayed. Eleven railroads used no such device.

One elevated electric road reported on the elevated structures and subways as follows:

"On the elevated structure and in the subways screw spikes can be installed or taken out as quickly as cut spikes. This is due undoubtedly to the limited space in which to work and the fact that screw spikes are installed or removed by means of pneumatic tools. Without question for this type of service, or any service requiring frequent renewal of rail, screw spikes will prolong the life of the ties and will result in better track."

Another railroad advised: "For ordinary maintenance no power tools are needed, but are of advantage for first installation; can be maintained by ordinary track labor."

With these replies have come some plans of details which, in the opinion of the roads using them, were important to observe before a fair trial of screw spike connection from the rail to the tie could be made.

As a result of these diverging opinions, it is the opinion of the Committee—

(1) That there is not sufficient data available, due to lack of general use, to show that the use of screw spikes will increase the durability of ties, except under special conditions.

(2) That there may be specific forms of track construction where screw spikes prolong the life of ties such as on elevated structures, and so-called permanent track where there is a more substantial foundation provided than on ordinary tie and ballast track.

It is suggested that this subject, requiring detailed inspection and report on those installations of screw spikes which have been successful, be assigned as a Committee subject for next year.

The following questions were asked as noted above:

1. Is it your experience that a screw spike permits longer life of the tie than a cut spike?

2. Kindly describe the conditions of design and application under which results are favorable to the screw spike, also conditions under which results are unfavorable and the cut spike permits longer life of tie, including—
   (a) General size and dimensions of screw spike and plate.
   (b) Amount of clear space left between 'the rail and the bottom of the screw spike, and what, if any, device is used to maintain this distance.
   (c) If treated ties are used, should the boring for the screw spikes be done before or after treatment?
   (d) Standard of track necessary, including kind of ties (kind of wood, treated or untreated), condition of ballast, character of subgrade (whether solid or liable to settle) and general drainage conditions.

In the answer to this question it is hoped there will be specified the standard of maintenance of track necessary to permit a favorable use of screw spikes compared with the cut spikes, if such has been obtained.

3. Has it been your experience that the screw spike becomes loosened before removal of tie is made necessary by other causes?
   If so, after what period, and what means should be taken to make the fastening secure.
4. Have you found a satisfactory lining to insert in the spike hole to make the screw spike secure again after it has become loose? If so, please describe the device and method of application.
5. After the wood has become loose or decayed around the screw spike, have you developed any satisfactory plug to insert in the tie and thus secure a firmer hold? If so, please describe the plug and method of application. Under these conditions do you replace the screw spike with a cut spike?
6. Should a screw spike be used as an anchor, or should it be kept free from the slots in the angle plates?
7. Can a screw spike be used to advantage to hold frogs, switches and turnout derails, and if so, what change in standards for cut spike is required to permit this use of screw spikes?
8. What is the effect on maintenance of the screw spikes as compared with the cut spikes in gaging of track, shimming, surfacing and lining, in its effect on the ties?
9. What effect does the use of screw spikes have on the life of ties when derailments, wrecks or broken rails occur?
10. What is your practice as regards spiking in replacing rail with new rail having different width of base?
11. Does the screw spike have any advantage over the cut spike in prolonging the life of the tie unless the tie is bored and treated before the screw spike is applied?
12. Are any particular forms of power tools in use in the field necessary to permit economical installation and maintenance of screw spikes in their effect on the ties? If so, please indicate what they are.
13. Can a screw spike be installed and maintained with advantage to the tie with our ordinary track laborers, or does it require a carpenter or semi-skilled mechanic in order to do justice to the work?

(3) REPORT ON METHODS IN USE BY VARIOUS RAILWAYS FOR CONTROLLING TIE RENEWALS.

Our study of the replies to inquiries in last year's investigation of methods for controlling tie renewals indicates a wide divergence of methods under apparent similarity of organization and physical conditions.

This suggests the possibility of developing a uniform method of determining the essentials necessary to control tie renewals, namely:

(1) Preliminary physical inspection of ties in track—based on a predetermined renewal standard.

(2) Field checks of the preliminary inspection in whole or in part.

(3) Utilization of statistics as a further check on tie renewals and the determination of final allotment.

(4) Checking results obtained.

The tabulations of replies received from one hundred railroads with an aggregate mileage of 223,000 would indicate that there are three general methods for determining the number of ties to be renewed.

(a) Field inspection by section foremen, supervisor or roadmaster.
(b) Inspection by tie inspector.
(c) Determination by statistics.

Evidence should be obtained to disclose which method is best suited to local conditions and type of organization to insure following predetermined standards of renewal and avoid divided responsibility for safe maintenance.

Information at hand does not indicate the best methods of obtaining effective field checks to secure economy and safety.

The question arises as to the relative importance of statistics as compared to field inspection as a further check on tie renewals.

The best methods of final allotment of tie supply should be further developed.

It is evident that an inspection of ties removed from track affords the best means of checking extravagance and placing the responsibility for same. This leads to the determination of the best method for making an independent check and devising means for determining and avoiding inadequate renewals.

(4) RECOMMEND PROPER DIMENSIONS FOR CROSS-TIES.

The Committee has no information to present on this subject this year.

(5) USE OF FORMS M. W. 301, 302, 303, 304.

See Proceedings Volume 19, page 369.

(6) REPORT ON TRIALS OF SUBSTITUTE TIES.

The usual report is attached.

CONCLUSIONS.

(1) Your Committee recommends that forms Nos. M. W. 301, 302, 303, 304 be withdrawn from the Manual.

(2) That the report on the design of tie-plates and track spikes on the durability of cross-ties be received as information.

(3) That the report as to methods in use by various railroads for controlling tie renewals be received as information.

(4) That the report on substitute ties be received as information.

Respectfully submitted,

THE COMMITTEE ON TIES.

Appendix A.

TRIALS OF SUBSTITUTE TIES.

Atchison, Topeka & Santa Fe Railroad—Eastern Lines.

UNIVERSAL; BAIRD; CARNEGIE.

(W. A. Guild, Acting Engineer, E. D.; January 14, 1919.)

UNIVERSAL TIES.—These are located in the Chicago Yard between milepost 1 and 2 and in front of the depot at Florence, Kansas. Those at Chicago were placed in the eastbound main in March, 1911, and are 83 in number. They are still in the track and have not been disturbed since they were placed, with the exception of changing the insulation, which was done about two years ago. Considerable corrosion has taken place, but not to the extent of rendering the tie unserviceable. Those at Florence are still in fair condition. And in relaying the 85-lb. A.S.C.E. rail with 90-lb. Santa Fe rail last year, we found a number of the wooden blocks in these ties decayed and replaced all of them. We found the bolts holding these blocks in good condition and practically all of them were re-used, as was some of the insulation.

BAIRD TIES.—Report of Baird ties, shown on page 387 of Volume 19, will remain the same for this year, as there has been no change in these ties during the past year and on account of there being only three of them, it is not possible to judge their ability to keep track in line, although there would probably be some trouble experienced in keeping the track in line were all of the ties of this make.

CARNEGIE TIES.—The Carnegie steel ties in service at Chanute, Kansas, and Newton, Kansas, are in fair condition and have been giving very good service. The only trouble that has been experienced with this tie has been with the rail clip and bolt which holds it in place. Both of these are thought to be too light, as is also the top flange of the I-beam, and it is thought that if 1-inch bolts were used in place of ⅝-inch bolts, together with nutlocks, that the clips would not have to be renewed as often as under present conditions and there would be less danger of the track spreading.

Baltimore & Ohio Railroad—Eastern Lines.

METAL TIE CORPORATION TIE; HARDMAN TIE.

(E. Stimson, General Superintendent Maintenance of Way and Structures; January 10, 1919.)

The metal ties located at Martinsburg, West Virginia, are still in service, about half of the wooden blocks having been renewed in the past six months.

The Hardman ties located at Baltimore, Maryland, have only been in service since May, 1917, and were alternated with wooden ties.

From recent inspection the indication would be that these ties will have to be removed from track within the next year.

Bessemer & Lake Erie Railroad Company.

CARNEGIE.

(H. T. Porter, Chief Engineer; December 4, 1918.)

Due to war conditions, we have not received any steel ties since 1915, and it is probable that we will not receive any in the near future.

Nothing of special interest has developed since our last report to the Committee and we, therefore, have no further information to furnish at this time.

Buffalo, Rochester & Pittsburgh Railway Company.

CARNEGIE.

(E. F. Robinson, Chief Engineer; November 29, 1918.)

The 1500 Carnegie steel ties were removed from our main track at Colden, N. Y., last month, account being unfit for further service. We still have a few of these ties in our main tracks at several water stations where locomotive ash pans are cleaned.

Chicago & Alton Railroad.

RAILWAY TIE CORPORATION STEEL SIMPLEX.

(H. T. Douglas Jr., Chief Engineer; December 4, 1918.)

We still have the Railway Tie Corporation steel ties in our track and they are giving excellent satisfaction.

A few months ago we removed all the Simplex ties from our track because the fastenings were beginning to badly need attention.

Chicago, Burlington & Quincy Railroad.

UNIVERSAL.

(W. L. Breckinridge, Chief Engineer; January 15, 1919.)

The Universal steel ties which we had in track for experiment were all removed April 30, 1917.

Cleveland, Cincinnati, Chicago & St. Louis Railroad.

CARNEGIE.

(C. A. Paquette, Chief Engineer; December 2, 1918.)

During the past year another one of the Carnegie steel ties failed in the track. The failure was in every respect similar to the one reported in 1917.

Delaware & Hudson Company.

CARNEGIE.

(James MacMartin, Chief Engineer; November 29, 1918.)

We are not making any tests of ties on this railroad at the present time.

Duluth & Iron Range Railroad.

CARNEGIE.

(W. A. Clark, Chief Engineer; December 2, 1918.)

We have nothing to report in connection with our installation of Carnegie steel ties.

Duluth, Missabe & Northern Railroad.

CARNEGIE.

(W. A. Clark, Chief Engineer; December 2, 1918.)

The installation of Carnegie steel ties is giving satisfactory service and there have been no developments during the last year to report.

Elgin, Joliet & Eastern Railroad.

BATES; CARNEGIE.

(A. Montzheimer, Chief Engineer; November 29, 1918.)

The only substitute ties we have on the Elgin, Joliet & Eastern Railroad are the 62 Bates concrete ties at Whiting, Indiana, and the Carnegie steel switch and cross-ties, which we have at various points on the Elgin, Joliet & Eastern Railroad.

Our last report gave the exact number of steel cross-ties in tracks and the number of sets of steel switch ties in tracks.

We have no other substitute ties and the above-mentioned ties are still performing good service.

Florida East Coast Railroad.

PERCIVAL CONCRETE.

(E. Ben Carter, Chief Engineer; November 30, 1918.)

Regarding the Percival concrete tie which we have installed in our road at St. Augustine:

1. The type of the tie or sleeper used is a concrete body with a gum-wood cushion between the concrete and the rail, 16 ties being used under one 30-foot rail.
2. The ties have been installed since March, 1906.
3. They are in one continuous section.
4. Not yet determined as to whether we will use more concrete ties or not. Heretofore the cost has been too great for general adoption.
5. No signs yet of cracking, and no signs of disintegration.
6. The road where the ties are laid is in our main line, subject to the heaviest and most continuous passenger and goods traffic we have, the weight of the rail being A.S.C.E. section 70 lbs. to the yard.
7. No difficulty in maintaining the surface, or, rather there would not be any if the bottom of the ties were flat instead of "V" shaped. It is presumed that the object of making them "V" shape was to avoid cost of material and its added weight. I object to the "V" shaped bottom. However, I was advised by Mr. Percival in March, 1914, that the "improved Percival tie" would overcome that difficulty, as it was to be made flat at the ends with a "V" shaped center only 22 inches long. I have not seen any of the improved type.
8. The resiliency is as good as it would be with any other tie. The shock between the rail and the tie is taken up by the wooden cushion, and I do not notice any apparent difference between the concrete tie and

the wood tie as to its elasticity on the roadbed. Because of the short distance covered by our concrete ties it is impossible to detect them when passing over them.

9. The type of fastener is a screw spike with a large head which projects into the flange of the rail. This passes through the wooden cushion and into a metal socket case in the tie at the time of its fabrication. The holding power seems to be excellent, and requires but little attention.

Lake Champlain & Moriah Railroad.

CARNEGIE.

(M. Moore, Superintendent; December 2, 1918.)

The Carnegie steel ties are in track as originally placed and are still giving us satisfactory service.

Lake Erie & Western Railroad.

BUHRER.

(J. K. Conner, Chief Engineer; December 5, 1918.)

In regard to Buhrer concrete ties which we have in our track at Tipton: We still have seven of these ties in our track, but two of them have failed and it will be necessary to renew them within a short time. This leaves five of the ties in our track in good condition.

Lehigh Valley Railroad.

METAL ON CONCRETE BASE.

(G. L. Moore, Engineer Maintenance of Way; December 6, 1918.)

The ties reported on page 891 of Vol. 11 of the Proceedings of the American Railway Engineering Association were metal ties installed on concrete base beneath the depressed ash car track at ashpits.

These ashpits have since been converted into water pits and the metal ties abandoned.

No other tests of substitute ties are being conducted on this road.

Long Island Railroad.

CARNEGIE.

(J. R. Savage, General Manager; December 13, 1918.)

We have about twenty-five Carnegie steel ties in our tracks at "HX" Tower, Hicksville, which were put in tracks during the month of May, 1909, and no repairs of any description have been made since their installation, and recent investigation of them revealed the fact that all fastenings are in good condition.

Midvale Steel and Ordnance Company—Nicetown Works.

SNYDER.

(R. Furness, Assistant Superintendent; December 3, 1918.)

All of the Snyder steel ties have been removed from the Midvale Steel and Ordnance Company's railway system at Nicetown.

We found that the first cost was about four times that of a white oak tie, and that the life of a steel tie at that time was indefinite, but the life of an oak tie was at least five years; in other words, we could buy four oak ties for the price of one steel tie and the oak ties would serve us over a period of twenty years. We subsequently found that the steel ties would last only from eight to ten years. The installation cost more than that of white oak ties. We would say, however, in favor of white oak ties, that we have a combination broad and narrow-gage system with many narrow gages running from this combination, and a large number of discarded white oak ties can be used in narrow-gage system, this making a big saving in ties that could not be made if we were using steel ties.

New York Central Railroad—Lines East.

BUHRER.

(J. V. Neubert, Engineer of Track; December 9, 1918.)

The Carnegie (Buhrer) steel ties which were located at Castleton were removed from main track in 1904 and 1905 and they have been installed in sidetracks and we have not continued the experiment of same.

We have a few other steel ties, but they are not in main track and are not under experiment.

New York Central Railroad—Lines West.

BUHRER.

(G. C. Cleveland, Chief Engineer, November 29, 1918.)

We have no metal, composite or concrete ties in service on our line at this time.

Northern Pacific Railroad.

CARNEGIE; UNIVERSAL.

(L. Yager, Engineer Maintenance of Way; December 9, 1918.)

We have no additional installations of substitute ties since last report, and our test has not developed anything worthy of report. We still have the few installations of Carnegie and Universal ties at coal docks and water stations, as well as the concrete roadbed in the State of Washington.

Oakland, Antioch & Eastern Railway.

GOODLETT PATENT.

(R. L. Lowry, Superintendent of Roadway; December 17, 1918.)

1. Location of test—Pleasant Hill, 18 miles from Oakland.
2. Number of ties in test—150.
3. Date installed—April 18, 1917.
4. Description of ties—Reinforced block with twisted rods to hold.
5. Photographs of track attached hereto.
6. Statement of character of track, i. e., weight of rail, depth and kind of ballast and spacing of ties—Rock ballast; 60 lbs.; 6 in. of rock under tie; 22 in. spacings.

7. Character and kind of traffic—Electric, freight and passenger.

These ties were placed in the track, but through an unfortunate circumstance of a derailment on a car that was heavily loaded on one side, running nearly two miles before stopping, the ties were torn up the entire distance, the heavy side of the car striking the concrete and cracking and breaking them so that we took them out. As to the tie, I believe it will solve the problem for use on electric roads, as well as on steam. After putting these ties in, we did not do anything to the track for nearly four months, watching the action to see whether they would need to be tamped up again, but, on account of the derailment, this was stopped.

GOODLETT TIES—OAKLAND, ANTIOCH & EASTERN RAILWAY.

Pennsylvania Railroad—Eastern Lines.

STANDARD STEEL TIES; LEONARD CONCRETE TIES; SNYDER COMPOSITE TIES; CARNEGIE STEEL TIES; CARNEGIE SWITCH TIES; MECHLING & SMITH STEEL TIES; SHANE STEEL TIES.

(W. G. Coughlin, Engineer Maintenance of Way; December 30, 1918.)

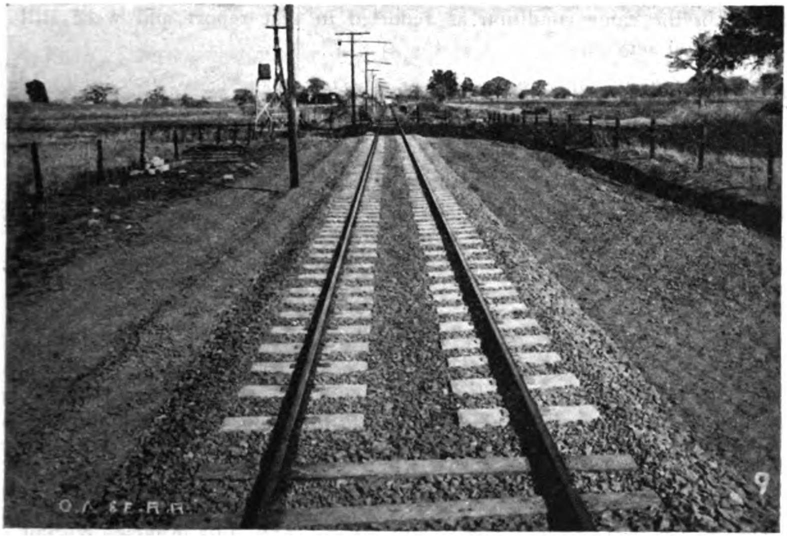
STANDARD STEEL TIES.—500 installed June, 1915, in eastward freight track, Philadelphia Division, A. & S. Branch, east of Lenover, Pa. A few of the wooden blocks have required renewal. Otherwise the ties are in good condition.

LEONARD CONCRETE TIES.—Six installed May, 1914, in eastward freight track, Philadelphia Division, A. & S. Branch, at Atglen, Pa. Removed September, 1918, on account of damage to rail fastenings by derailed

equipment. One tie broken in service; the concrete in the other five was in good condition when the ties were removed from track.

SNYDER COMPOSITE TIES.—821 in westbound track at Derry, Pittsburgh Division. In fair condition.

CARNEGIE STEEL TIES.—3000 installed November, 1913, in eastward freight track, Philadelphia Division, A. & S. Branch, east and west of Atglen, Pa.; 1607 removed in November and December, 1917; 382 removed in April, 1918, and 687 removed in July, 1918, all on account of web splitting and rivets becoming loose. This completes the removal of the 3000 ties. Their average life was 3 years 10 months.



GOODLETT TIES—OAKLAND, ANTIOCH & EASTERN RAILWAY.

CARNEGIE SWITCH TIES.—Of the four sets No. 8 and one set No. 10 turnouts installed in Pitcairn Yard approximately 90 per cent. have been removed on account of damage from derailments, with the exception of the headblocks whose removal was due to the ties buckling under the rail. The ties which were removed were badly corroded and their removal from this cause would have been necessary in a short time.

MECHLING & SMITH STEEL TIES.—80 remain in Wilkinsburg Yard, Pittsburgh Division. They are in fair condition.

SHANE STEEL TIES.—100 installed February, 1916, 45 renewed November, 1916, 35 removed December, 1916, 65 remain in track in fair condition.

Pennsylvania Railroad—Western Lines.

RIEGLER CONCRETE STEEL TIE.

(W. C. Cushing, Chief Engineer Maintenance; January 3, 1919.)

RIEGLER CONCRETE STEEL TIE.—The only substitute tie that we now have on the Pennsylvania Lines West of Pittsburgh is the Riegler concrete steel tie.

The fifteen ties which were placed in No. 1 Westward Passenger Track, west of Emsworth, in May, 1908, were transferred to No. 3 Eastward Freight Track in December, 1914, and are still in track.

A progress report was made of these ties on page 398, Volume 19, of the Proceedings of the American Railway Engineering Association. These ties were inspected December 19, 1918, and were found to be practically in the same condition as reported in that report and were still giving good service.

Pittsburgh, Shawmut & Northern Railroad.

CARNEGIE.

(J. N. Thompson, Secretary to Receiver; December 17, 1918.)

In regard to Carnegie I-beam steel ties, installed on this Company's Byrnedale Branch: Since the last report it has been necessary to remove about one hundred of these ties account of the web crushing.

We have made no other installation of substitute ties.

Pere Marquette Railroad.

"ALFRED."

(H. A. Cassil, Engineer Maintenance of Way; January 16, 1919.)

The "Alfred" ties were originally applied to the track at Saginaw, Michigan. At the present time we are able to locate seven of them.

Riverside, Rialto & Pacific Railway.

WOLF.

(Arthur Maguire, Engineer Maintenance of Way, Los Angeles & Salt Lake Railroad; January 6, 1919.)

Relative to concrete ties in use on the Riverside, Rialto & Pacific Railway line, between Riverside and Crestmore, California: A recent inspection of the ties showed them to be in good condition. Traffic on the line consists of ten electric motor cars each way daily. The cars weigh about 65 tons. Also two movements each way daily of switch engines, weighing about 150,000 lbs. on drivers.

REPORT OF COMMITTEE VII—ON WOODEN BRIDGES AND TRESTLES.

W. H. Hoyt, *Chairman;*
H. Austill,
F. Auryansen,
A. D. Case,
E. A. Frink,
W. L. Darden,
E. A. Hadley,
G. A. Haggander,
F. F. Hanly,
H. T. Hazen,
A. O. Ridgway, *Vice-Chairman;*
C. S. Heritage,
F. S. Schwinn,
C. S. Sheldon,
I. L. Simmons,
D. W. Smith,
A. M. VanAuken,
W. H. Vance,
D. R. Young,

Committee.

To the American Railway and Engineering Association:

The following subjects were assigned for consideration of your Committee during the past year:

1. Make critical examination of the subject-matter in the Manual and especially consider:
(a) Expanding table of allowable stresses on page 244 to include treated timber.

2. Report on design of docks and wharves; coal and ore wharves, including various details, such as bulkheads, cribwork, dry docks, ferry slips, and the necessary machinery, conveyors and fixtures for the economical operation of property of this kind.

3. Report on classifications and grading rules for all lumber and timber used in the Construction and Maintenance of Way Departments of railways.

4. Report on specifications for construction timbers and building lumber.

5. From studies 3 and 4, draw up in unified form a set of specifications for construction timbers and building lumber for use on railways, showing each kind and quality of lumber or timber which is suitable for each of the different classes of work on a railway.

6. Report on specifications for timber which is to be treated with a preservative substance, co-operating with the Committee on Wood Preservation.

Your Committee was divided into three sub-committees to consider and report upon Subject No. 1, Subjects Nos. 3, 4 and 5, and Subject No. 6.

A general meeting was held in the Association rooms in Chicago, December 4, 1918, and was attended by the following: Messrs. Ridgway, Haggander, Hadley, VanAuken and Hoyt.

At this meeting it was decided that the work for the past year would be submitted as a progress report only.

(1) REVISION OF MANUAL.

SUB-COMMITTEE No. 1—A. O. RIDGWAY, *Chairman.*

MAKE CRITICAL EXAMINATION OF THE SUBJECT-MATTER IN THE MANUAL, AND ESPECIALLY CONSIDER:

(a) Expanding table of allowable stresses on page 244 to include treated timber.

Your Committee has no recommendations to make as to the subject-matter in the Manual except in the way of intensive revision and re-writing of the entire chapter on Wooden Bridges and Trestles.

It is not thought expedient to advise such revision at this time or at least until a new edition of the Manual is issued.

The especial consideration of expanding table of allowable stresses on page 244 to include treated timber has been given extensive study during the past year. An investigation of experiments for determining the comparative strength values of untreated and treated timber in large sticks discloses the fact that there are extant only two published records of such experimental tests. One of these is to be found in Bulletin Number 286 of the United States Department of Agriculture, and the other consists of a monograph by H. B. MacFarland, Engineer of Tests for the Atchison, Topeka & Santa Fe Railway System, beginning on page 281, Volume 17, of the Proceedings of the Association.

The United States Department of Agriculture conducted tests in cooperation with the Illinois Central Railroad to determine strength values for bridge stringers manufactured from three kinds of wood and treated commercially.

Without describing in detail these tests, it is perhaps advisable to call attention to the following brief summary of the results:

KIND OF WOOD	MODULUS OF RUPTURE			FIBER STRESS AT ELASTIC LIMIT			LONGITUDINAL SHEAR AT FAILURE		
	Natural	Treated	Dec. %	Natural	Treated	Dec. %	Natural	Treated	Dec. %
Longleaf Pine..	5151	5132	00.0	3346	2898	13.4	454	449	01.0
Loblolly Pine..	4858	4150	14.6	2738	2080	24 2	455	388	14.7
Douglas Fir...	5811	3756	35.3	4117	2761	32.9	386	249	35.5

The tests conducted by Mr. MacFarland for the Santa Fe Railway were confined to full-sized Douglas Fir bridge stringers. We therefore have only comparative testing of untreated and treated timber, in large sized sticks, for three kinds of wood, namely, Longleaf Pine, Loblolly Pine and Douglas Fir. There are only two series of experiments on any one of these three kinds of wood, namely, Douglas Fir, and a comparative summary of these appears thus:

ELEMENT OF STRENGTH	PER CENT DECREASE BY TREATMENT	
	U. S. Dept. Agriculture	Santa Fe Ry.
Modulus of Rupture	35.3	18.0
Fiber Stress at Elastic Limit	32.9	18.0
Longitudinal Shear at Failure	35.5	18.9

It is to be observed from the above that no definite conclusion is warranted as to the decrease in elements of strength due to the treatment of the three kinds of wood on which tests were conducted, and when an attempt is made to prescribe values or safe unit stresses for treated wood of other kinds appearing in the table on page 244 of the Manual, all such efforts seem of the greatest futility.

Attention is called to the wide divergence of results secured from the testing of Douglas Fir by the United States Department of Agriculture and the Santa Fe Railway as shown above. While strength values of the treated timber are found by the Department of Agriculture to be from 33 to 36 per cent. lower than those values for the same sort of sticks untreated, the Santa Fe Railway finds these same values to be in the treated material only 18 or 19 per cent. less than for untreated material.

It is clearly brought out in the published record of both these series of tests that neither the character nor the quantity of the preservative itself has any appreciable effect in reducing the strength values of timber but that such decrease is due entirely to the process of treatment. Moreover, it appears evident that some kinds of wood are injured by the process of treatment while others may not be appreciably affected thereby as is evident from the Department of Agriculture tests on Longleaf Pine, which wood shows little decrease in strength by treatment.

As a result of the study devoted to this subject by your Committee a definite recommendation seems inadvisable at this time for expanding Table of Allowable Stresses, on page 244 of the Manual, to include permissible stresses for treated timber.

Until further experiments have been conducted in the way of comparing treated and untreated timber in large sticks, it is perhaps best for each engineer to use his own judgment as to the lower values of allowable stresses which should be applied in the design of treated timber trestles, keeping in mind that such values may be as much as one-third lower than for untreated material.

TESTS OF STRUCTURAL TIMBERS, UNITED STATES DEPARTMENT OF AGRICULTURE, BULLETIN No. 286.
1915.

Partially Air Dry Longleaf and Loblolly Pine and Green Douglas Fir. Large sticks 8 in. by 16 in. by 28 ft. and 32 ft. Small pieces 2 in. by 2 in. by 30 in. cut from large sticks after failure.

N = Timber in natural condition. T = Treated with creosote. S = Steaming process. B = Boiling process.

Modulus of elasticity is given for thousands of pounds per square inch.

Kind of Wood		Modulus of Rupture				Fiber Stress Elas. Limit				Modulus of Elasticity			
		Large		Small		Large		Small		Large		Small	
		N	T	N	T	N	T	N	T	N	T	N	T
Longleaf....	S	5151	5132	9507	9036	3346	2898	5623	5365	1409	1275	1493	1434
Loblolly....	S	4858	4150	8605	6571	2738	2080	5109	3531	1296	1155	1350	1104
Douglas Fir	B	5690	3820	7923	6216	3980	2980	4450	3434	1569	1542	1595	1486
Douglas Fir	S	5430	3540	......	......	3740	2370	......	......	1557	1412	......	......

Relation of results as between treated and untreated timber. If values for untreated timber N = 100, then values for treated timber would be as follows:

KIND OF WOOD		Modulus of Rupture		Fiber Stress Elastic Limit		Modulus of Elasticity	
		Large	Small	Large	Small	Large	Small
Longleaf..............................	...	100	95	87	95	91	96
Loblolly..............................	...	85	76	76	69	89	82
Douglas Fir..........................	B	67	78	75	77	98	93
Douglas Fir..........................	S	65	....	63	....	93	....

Relation of results as between large sticks and small pieces. If values for small pieces = 100, then values for large sticks would be as follows:

KIND OF WOOD		Modulus of Rupture		Fiber Stress Elastic Limit		Modulus of Elasticity	
		N	T	N	T	N	T
Longleaf..............................	...	54	56	60	54	94	89
Loblolly..............................	..	56	63	54	59	96	105
Douglas Fir..........................	B	72	62	89	87	98	104

Comparison of Tests on Creosoted and Untreated Large Sticks of Douglas Fir.

Boiling Process of Treatment.

Moisture Untreated Specimens: U. S. 33.6 per cent., Santa Fe 39.4 per cent.

Treated Specimens: U. S. 28.5 per cent. Santa Fe 26.2 per cent.

AUTHORITY	Modulus of Rupture			Stress at Elastic Limit			Modulus of Elasticity		
	N	T	Decr. %	N	T	Decr. %	N	T	Incr. %
U. S. Dept. Agriculture....	5690	3820	33	3980	2980	25	1569	1542	*1.7
Santa Fe..................	5691	4680	18	4269	3481	18	1702	1666	2.1

*Decrease.

Comparison of Tests on Creosoted and Untreated Large Sticks of Douglas Fir.

Boiling Process of Treatment.

Moisture Untreated Specimens: U. S. 15.3 per cent., Santa Fe 39.4 per cent.

Treated Specimens: U. S. 19.5 per cent. Santa Fe 26.2 per cent.

AUTHORITY	Modulus of Rupture			Stress at Elastic Limit			Modulus of Elasticity		
	N	T	Decr. %	N	T	Decr. %	N	T	Decr. %
U. S. Dept. Agriculture....	6240	3860	38	4560	2840	38	1809	1560	13.8
Santa Fe..................	5691	4680	18	4269	3481	18	1702	1666	2.1

Comparison of Tests on Creosoted and Untreated Large Sticks of Douglas Fir.

Moisture Treated Specimens: U. S. 33.0 per cent., Santa Fe 26.2 per cent.

U. S. Specimens treated by steaming process, S. F. by boiling.

Moisture Untreated Specimens: U. S. 37.5 per cent., Santa Fe 39.4 per cent.

AUTHORITY	Modulus of Rupture			Stress at Elastic Limit			Modulus of Elasticity		
	N	T	Decr. %	N	T	Decr. %	N	T	Decr. %
U. S. Dept. Agriculture....	5430	3540	35	3740	2370	37	1557	1412	9.3
Santa Fe..................	5691	4680	18	4269	3481	18	1702	1666	2.1

DECREASE IN STRENGTH OF TREATED DOUGLAS FIR.

Number of Tests: U. S. 108, Santa Fe 52.

FACTOR	Decrease Per Cent. Treated Timber		
	U. S.	S. F.	Difference
Modulus of Rupture	35.3	18.0	17.3
Stress at Elastic Limit	33.3	18.0	15.3
Horizontal Shear at Failure	35.6	18.9	16.7

(2) DESIGN OF DOCKS AND WHARVES.

No Sub-Committee was appointed to consider this assignment for this year and no progress report will be made. This work will be carried over for future consideration.

(3) REPORT ON CLASSIFICATION AND GRADING RULES.

(4) REPORT ON SPECIFICATIONS FOR TIMBER AND BUILDING LUMBER.

(5) FROM ABOVE STUDIES, DRAW UP IN UNIFIED FORM A SET OF SPECIFICATIONS FOR CONSTRUCTION TIMBERS AND BUILDING LUMBER FOR USE ON RAILWAYS, SHOWING EACH KIND AND QUALITY OF LUMBER AND TIMBER WHICH IS SUITABLE FOR EACH OF THE DIFFERENT CLASSES OF WORK ON A RAILWAY.

SUB-COMMITTEE NO. 3—W. H. HOYT, *Chairman*.

The Sub-Committee, which has been studying the above assignment, wish to submit a progress report.

Our investigations and studies during the past year lead us to believe that an entire rearrangement of the chapter on Wooden Bridges and Trestles, as now published in the Manual, would be profitable, and we submit herewith a detailed suggestion for such rearrangement. We also are of the opinion that a separate chapter to be headed "Timber and Lumber," which should contain General Specifications and Classification and Grading Rules for all kinds of timber and lumber to be used for each of the different classes of work on railways, might well be published in the Manual. We submit herewith a tentative form with abbreviated suggestions of the material to be carried in such chapter.

In studying the matter of Specifications and Classification and Grading Rules for Timber and Lumber, the question arises as to whether it were better to arrange a general specification that might be used as a basis for all kinds of material of this class and for all purposes on railways, or whether it would be better to attempt to draw individual specifications for each and every kind of material and class of work.

The plan of drawing a general specification would greatly condense the printed matter in the Manual, bring it under one head and make it of easy reference and ready use. The drafting of individual specifications for each individual kind of material would require a large amount of space and, if carried out in that way, should be placed under the work of the different committees using such material. This would tend to make the Manual bulky and the work scattered. Your Committee desires advice from the members of the Association as to the best plan to follow in this matter, and will be glad to consider their recommendations in its future work.

We submit herewith tentative general Specifications and Classification and Grading Rules developed during the study of this work for the past year. This work will give the members of the Association some idea of what general specifications of this kind would cover. These specifications have been drawn up after careful consideration and a thorough study of the work now standing in the Manual; recommendations and reports of committees as published in the Proceedings, especially the Special Committee on Classification and Grading Rules; the specifications of the American Society of Testing Materials; the work of the United States Forestry Board; reports of laboratory studies from various scientific institutions; a detailed study of the Standard Specification and Grading Rules of all the lumber manufacturers' associations, and various other sources.

It has been our attempt to draw up such general specifications that they might be referred to as standard for material of this kind under all circumstances. Special attention has been given to standard manufacturing processes so that no decided changes will be necessary in the best practices now followed by the manufacturers, yet satisfactory material may be obtained by the railways at reasonable prices.

(6) Report on Specifications for Timber to Be Treated With a Preservative, Co-operating With Committee on Wood Preservation.

Sub-Committee No. 4—C. S. Heritage, *Chairman.*

Committee on above subject have been making a study of the General Specifications referred to by Sub-Committee No. 3, and expect to make definite recommendations in regard to certain requirements applicable to timber which is to be creosoted. Committee reports progress.

(Proposed Chapter on)

Timber and Lumber.

(Prepared by Committee VII—Wooden Bridges and Trestles.)

Structural Timber.

(Pages 221 and 222, Manual, as at present.)

Standard Names for Varieties of Structural Timber.

(As printed herewith.)

Definitions of Defects Applicable to All Timber and Lumber.

(As printed herewith.)

Illustrations of Defects.

(Cuts of photographs with timber defects as listed herewith.)

(Follow recommendation of Committee on Revision of Manual, Appendix "A," page 586, Vol. 19, as follows:

"That all illustrations, tables and diagrams in the Manual be designated by the number of the page on which they appear instead of being numbered consecutively, using sub-scripts when more than one revision appears on a single page.")

Defects of Manufacture.

(As printed herewith.)

Standard Sizes.

(As printed herewith.)

General Instructions on Grading Timber and Lumber.

(As printed herewith.)

Definitions Relating to Select Structural Grade for Bridge and Trestle Timbers.

(As printed herewith.)

Select Structural Grade for Bridge and Trestle Timber, Douglas Fir, and Southern Yellow Pine Specifications.

(As printed herewith.)

(Also add explanatory note, Manual, page 233, and diagram, page 916, Volume 16.)

(See Vol. 17 of Proceedings, pages 408 to 411, Vol. 18, pages 823, 824 and 825, for material from which composite specifications for above were drawn.)

Select Structural Grade for Bridge and Trestle Timber, Douglas Fir and Southern Yellow Pine to Be Treated.

(These specifications to be drawn up by Sub-Committee No. 4.)

Commercial Grades for Timber and Lumber.

(As printed herewith.)

Specifications for Construction Oak Timber.

(See Manual, pages 631 to 643, also consult list of pages in Manual affected by proposed revision, and printed herewith.)

Classification and Grading Rules for Cypress Lumber and Shingles.

(See Manual, pages 643 to 652, inclusive, leaving out definitions of defects and grouping cuts according to accompanying list.)

Classification and Grading Rules for Hemlock Lumber.

(Use material in Volume 16, pages 907 to 914, inclusive, leaving out general instructions and definitions of defects and figures. These specifications were recommended and accepted as standard. See Volume 17, page 917.)

Classification of the Uses of Timber and Lumber.

(As printed herewith.)

(This is a development of the work of sub-committee on grading of lumber, see pages 826 and 827, Volume 18, Proceedings.)

Working Unit Stresses for Structural Timber, Expressed in Pounds per Square Inch.

(See page 244, Manual.)

Note—Committee on Wooden Bridges and Trestles, page 585, Vol. 19 of Proceedings, recommended as follows:

"Revision of Manual." Revise the table of recommended stresses on page 244 of the Manual and enlarge it to include stresses in treated timber."

Note—It would seem best at present to include page 244 in Manual without change.

List of Pages in Manual Affected by Proposed Revision.

GRADING OF LUMBER.

Page 591—Covered by revisions.
Page 592—Fig. left out.
Page 593—Cut of large knot left out.
Definitions covered by revisions.
Cut of small spike knot used as shown on list of figures.
Page 594—Fig. Large Spike Knot used as shown on list of figures.
Fig. loose knot not used.
Page 595—Cut Pitch Knot used as shown on list of figures.
Cut rotten knot not used.
Page 596—Fig. Cluster of Knots and Fig. Closed Small Pitch Pocket used as shown on list of figures.
Definitions covered by revisions.
Page 597—Fig. Solid Pitch and Fig. Large Open Pitch Pocket used as shown on list of figures.
Definitions covered by revisions.
Page 598—Fig. Small Pitch Streak used as shown on list of figures.
Definitions covered by revision.
Pages 599, 600, 601, 602, 603, 604, 605, 606, 607 and 608—All covered except grades for Tank Stock, Turned Porch, Columns, Fencing and Lath size.
Page 609—Fig. Pin Knot and Fig. Standard Knot left out.
Page 610—Fig. Large Knot and Fig. Spike Knot left out.
Page 611—Definitions covered by revisions.
Fig. "Loose Knot" and Fig. "Pith Knot" left out.
Page 612—Fig. "Encased Knot" and Fig. "Rotten Knot" left out.
Definitions covered by revisions.
Page 613—Definitions covered by revisions.
Fig. Pitch Streak left out.

Pages 614, 615, 616, 617, 618, 619 and 620—Except Wagon Bottoms, which is left out.
Pages 621, 622, 623 and 624—Except Fencing, which is left out.
Page 625—Fencing left out.
Pages 626, 627 and 628—Except Lath, which is left out.
Page 629—Except Byrkit Lath, which is left out.
Pages 630 and 631—Except Pickets, which is left out, are all covered by revised grades.

Specifications for Construction Oak.

Timbers left unchanged except to be added at end of lumber grade section.

Page 632—Paragraph at top to be carried with matter on previous page.
Paragraph, Construction Oak unchanged.
Page 632—Standard Defects have been covered in general group definition and need not be repeated here, hence leave out.
Page 633—Fig. Sound Knot and Fig. Large Knot used as shown on list.
Page 634—Fig. Loose Knot and Fig. Pith Knot used as shown on list.
Page 635—Fig. Rotten Knot and Fig. Pin Knot used as shown on list.
Page 636—Fig. Standard Knot used as shown on list.
Fig. Spike Knot not showing oak; provide a new one.
Page 637—Fig. Burl Knot and Fig. Pin Worm used as shown on list.
Page 638—Fig. Wooden Rafting Pin Hole and Fig. Spot Worm used as shown on list.
Definitions covered by revisions.
Page 639—Definitions covered by revisions.
Fig. Metal Rafting Pin Hole and Fig. Grub Worm Holes used as shown on list.
Page 640—Definitions down to "Standard Names for Construction of Oak" covered by definitions already given.
Used paragraph "Standard Names for Construction Oak."
Page 641—"Specifications for Structural Oak Timbers" not changed.
Page 642—Not changed.
Page 643—Not changed, except to leave out definitions at bottom, which are covered by one set.
Page 644—Definitions covered as revised. Fig. Standard Sound Knot and Rotten Knot used as shown on list.
Page 645—Definitions covered as revised.
Fig. Pecky Cypress used as shown on list.
Standard lengths, etc., not changed.
Page 646—Fig. Two Small Knots equal to one Standard Knot, and Fig. Small Sound Knot used as shown on list.
Pages 647, 648, 649, 650, 651 and 652—Unchanged.

(Proposed Revision of)

COMMITTEE VII.

WOODEN BRIDGES AND TRESTLES.

Definitions.

(Manual, pages 219 and 220, as at present.)

Piles and Pile Driving.

(Manual, pages 220 and 221, as at present.)

Specifications for Timber Piles.

(Manual, pages 235 and 236, as at present.)

Use of Guard Rails for Wooden Bridges and Trestles.

(Insert Manual, page 246, also recommendations for use of lag screws, Vol. 19, page 584.)

Specifications for Workmanship for Pile and Frame Trestles to Be Built Under Contract.

(Manual, pages 238 to 241, as at present.)

Pile Driving Principles of Practice.

(Manual, pages 241 to 243, as at present.)

Pile Record Form.

(Manual, page 245, as at present.)

Economic Analysis of Structures.

(Study pages 593 to 605, Proceedings, Vol. 19, with a view to developing formula, tables and diagram for general application to all structures and printing in the Manual.)

Economy Curves.

(Vol. 19, Monographs, pages 285, 290 and 291.)

List of Pages in Manual Affected by Proposed Revision, Wooden Bridges and Trestles.

Page 219—Unchanged.
Page 220—Unchanged.
Page 221—Unchanged.
Page 222—Unchanged down to title "Standard Defects of Structural Timber," which is revised and inserted later in arrangement.
Page 223—Revised as noted above.
Page 224—Revised as noted above.
Page 225—Fig. 1 and Fig. 2 to be inserted further on.
Page 226—Figs. 3 and 4 to be inserted further on.
Page 227—Figs. 5 and 6 to be inserted further on.
Page 228—Figs. 7 and 8 to be inserted further on.
Page 229—Figs. 9 and 10 to be separated and inserted further on.
Page 230—Title and subject matter revised to read as shown on accompanying sheets.
Inspection of Bridge and Trestle Timbers and accompanying paragraph to be left out.

Page 231—Revised under title "Select Structural Grade for Bridge and Trestle Timbers" and inserted later.

Page 233—Explanatory note for Structural Grade, etc.
Revised only as to title and inserted later.
Standard Specifications for Douglas Fir and Western Hemlock Bridge and Trestle Timbers covered by revisions under density rule and inserted later.

Page 234—Covered by note above.

Page 235—Upper half covered by note above.

Page 235—Lower half and on through the section placed at end of this section relating to Timber and Lumber grades.

(Revised January 6, 1919.)

STANDARD NAMES FOR VARIETIES OF STRUCTURAL TIMBER.

SOUTHERN YELLOW PINE.—This term includes the species of yellow pine growing in the Southern states from Virginia to Texas, that is, the pines hitherto known as longleaf pine (Pinus palustris), shortleaf pine (Pinus echinata), loblolly pine (Pinus taeda), Cuban pine (Pinus heterophylla) and pond pine (Pinus serotina).

DOUGLAS FIR.—The term "Douglas Fir" covers the timber known as yellow fir, red fir, Western fir, Washington fir, Oregon or Puget Sound fir or pine, Northwest and West Coast fir.

NORWAY PINE covers what is known also as "Red Pine" and Banksian (Pinus Banksiana).

HEMLOCK covers Southern or Eastern hemlock; that is, hemlock from all states east of and including Minnesota.

WESTERN HEMLOCK covers hemlock from the Pacific Coast.

SPRUCE covers Eastern spruce; that is, the spruce timber coming from points east of and including Minnesota.

WESTERN SPRUCE covers spruce timber from the Pacific Coast.

WHITE PINE covers the timber which has hitherto been known as white pine, from Maine, Michigan, Wisconsin and Minnesota.

IDAHO WHITE PINE covers the variety of white pine from Western Montana, Northern Idaho and Eastern Washington.

WESTERN PINE covers the timber sold as white pine coming from Arizona, California, New Mexico, Colorado, Oregon and Washington. This is the timber sometimes known as "Western Yellow Pine," or "Ponderosa Pine," or "California White Pine," or "Western White Pine."

WESTERN LARCH covers the species of Larch or Tamarack from the Rocky Mountains and Pacific Coast regions.

TAMARACK covers the timber known as "Tamarack," or "Eastern Tamarack," from states east of and including Minnesota.

CEDAR covers White Cedars: Thuya occidentalis, Maine to Minnesota and northward; Chamœcyparis thyoides, Atlantic Coast from Maine to Mississippi; Chamœcyparis lawsoniana, along the coast line of Oregon; Libocedrus decurrens, Cascades and Sierra Nevada of Oregon

and California. Red Cedars: Thuya gigantea, Washington to Northern California and eastward to Montana; Juniperus virginiana, throughout United States.

Cypress (Taxodium distichum) covers bald cypress, black, white and red cypress, from swamp and overflow land along the coast and rivers of the Southern States.

Redwood includes the California wood usually known by that name.

Oak—Under this heading three classes of timber are used: (a) White Oak, to include White Oak, Burr Oak and Post Oak; (b) Red Oak, to include Red Oak, Scarlet Oak, Black Oak and all bastard oaks; (c) Chestnut Oak, to include only Chestnut Oak.

Definition of Defects.

Defect—Fault, blemish or mark of imperfection that will materially injure the strength or make the timber or lumber unsuitable for the use intended.

Natural Defects Applicable to All Timber and Lumber.

The mean or average diameter of knots or holes shall be considered in applying and construing these rules.

Tight or Sound Knot.—One which is solid across its face and is as hard as the wood surrounding it. It may be of any color, contain checks and is so fixed by growth or position that it will remain in its place in the piece.

Loose Knot.—One not firmly held in place by growth or position. (See Fig. 1.)

Pith Knot.—Sound knot with a pith hole not more than ¼ inch in diameter in the center. (See Fig. 2.)

Encased Knot.—One whose growth rings are not intergrown and homogenous with the growth rings of the piece it is in. The encasement of bark or pitch may be partial or complete. If intergrown partially or so fixed by growth or position that it will retain its place in the piece, it shall be considered a sound knot; if completely intergrown on one face it is a water-tight knot. (See Fig. 3.)

Rotten Knot.—One not as hard as the wood surrounding it. (See Fig. 4.)

Pin Knot.—Sound knot ½ inch or less in diameter. (See Fig. 5.)
For Oak—Sound knot ¾ inch or less in diameter.

Small Knot.—Tight sound knot ¾ inch or less in diameter. Two small knots are not to exceed in extent or damage one 1½-inch knot.

Standard Knot.—Sound knot 1½ inches or less in diameter. (See Fig. 6.)
For Oak— Sound knot 2 inches or less in diameter.
For Cypress—Sound knot 1¼ inches or less in diameter.

Large Knot.—Sound knot more than 1½ inches in diameter. (See Fig. 7.)
For Oak—Sound knot not more than 2 inches in diameter.

Round Knot.—One which is circular or oval in form.

Spike Knot.—One sawed in a lengthwise direction. (See Fig. 8.)

DIAGONAL GRAIN (including crooked grain, cross grain and spiral grain) is grain not parallel with all the edges of the piece.

WOODEN RAFTING PINHOLES sometimes appear on river timber which has been rafted when holes have been bored in the solid wood for securing the timber, and a solid plug or pin driven in the hole, completely filling it.

These defects must be treated and considered the same as knot defects.

Ordinary Metal Rafting Pin, Cant Hook or Chain Dog-hole is considered no defect.

GRUB WORM HOLES are usually from about ⅛ inch to 3/16 inch in width, and vary in length from about 1 inch to 1½ inches and are caused by grubs working in the wood.

PIN WORM HOLES are very small holes caused by minute insects or worms. These holes are usually not over 1/16 inch in diameter, the wood surrounding them is sound and does not show any evidence of the worm hole having any effect on the wood other than the opening.

SPOT WORM DEFECTS (also known as Flagworm Defects) are caused, like Pinworm holes, by minute insects or worms working on the timber during the growth. The size of the hole is about the same as Pinworm holes, but the surrounding wood shows a colored spot as evidence of the defect. This pot is usually sound and does not affect the strength of the piece.

BIRD PECKS are bruises apparently caused by bird pecks during the growth process of the timber and is not considered a defect.

PITCH POCKETS.—Openings between the grain of the wood, containing more or less pitch or bark and surrounded by sound grain wood; these shall be classified as small, standard or large pitch pockets.

A Pitch Pocket showing open on both sides of the piece ⅛ inch or more in width shall be considered the same as a knot hole.

SMALL PITCH POCKET.—One not over ⅛ inch wide. (See Fig. 9.)

STANDARD PITCH POCKET.—One not over ⅜ inch wide nor over 3 inches in length.

LARGE PITCH POCKET.—One over ⅜ inch wide or over 3 inches in length.

PITCH STREAK.—A well-defined accumulation of pitch at one point in the piece. When not sufficient to develop a well-defined streak, or where the fiber between the grain, that is, the coarse-grained fiber, usually termed "spring wood," is not saturated with pitch, it shall not be considered a defect.

SMALL PITCH STREAK shall be equivalent to not over one-twelfth the width and one-sixth the length of the piece it is in.

STANDARD PITCH STREAK shall be equivalent to not over one-sixth the width and one-third the length of the piece it is in.

SHAKES.—Splits or checks in timber which usually cause a separation of the wood between annual rings.

RING SHAKE.—An opening between the annual rings, usually showing only on the end of the piece.

THROUGH SHAKE.—A shake which extends between two faces of a piece of timber.

PITCH SHAKE.—A clearly defined seam or opening between the grain of the wood and may be either filled or not with granulated pitch.

CHECKS.—A small crack in the wood due to seasoning. Ordinary season checks such as occur in lumber properly covered in yard, or season checks of equal size in kiln-dried lumber shall not be considered defects.

"SAP."—Sap is the alburnum of a tree—the exterior part of the wood next to the bark. Sapwood is not considered a defect except as provided herein.

SOUND HEART.—The term "Sound Heart" is used whenever that part of the piece which was originally the central part, or core of the tree, is sound and solid, not decayed.

ROT, DOTE, RED HEART.—Any form of decay which may be evident either as a dark red discoloration not found in the sound wood or by the presence of white or rotten red spots, which shall be considered as a defect. Discoloration of the heart of the wood or stained heart must not be confounded with red or rotten streaks. The presence of rot is indicated by a decided softness of the wood where it is discolored or by small white spots resembling pin wormholes.

Water stain, or what are sometimes called scalded or burnt spots, usually caused by timber lying in the water under certain conditions before it is sawed, and burnt spots where timber is improperly piled green, are not considered defects, as they do not affect the strength of the piece.

WANE.—Wane is bark or the lack of wood, from any cause on edges of timber.

CROOK.—A deflection edgewise from a straight line in the length of a piece. The extent of crook shall be determined by drawing a straight line from end to end of the piece on the concave edge, and measuring from such line to the edge of piece at the point of greatest deflection.

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Defects of Manufacture, Applicable to All Timber and Lumber.

Defects in rough stock caused by improper manufacture and drying will reduce grade, unless they can be removed in dressing such stock to standard sizes.

In structural timber defects of manufacture have usually been omitted, being of minor significance.

Imperfect manufacture in dressed stock, such as torn grain, loosened grain, slight skips in dressing, wane, broken knots, mismatched, insufficient tongue or groove for flooring, ceiling, drop siding, etc., shall be considered defects, and will reduce the grade according as they are slight or serious in their effects on the use of the stock.

Torn grain consists of a part of the wood having been torn out in dressing. It occurs around knots and curly places and is of four distinct characters: slight, medium, heavy and deep. Slight torn grain shall not exceed $\frac{1}{32}$ inch in depth; medium $\frac{1}{16}$ and heavy ⅛ inch. Any torn grain heavier than ⅛ inch shall be termed deep.

Loosened grain consists in a point of one grain being torn loose from the next grain. It occurs on the heart side of the piece and is a serious defect, especially in flooring.

Chipped grain consists in a part of the surface being chipped or broken out in small particles below the line of cut and, as usually found, should not be classed as torn grain, and shall be considered a defect only when it unfits the piece for use intended.

Pieces of Flooring, Drop Siding or Partition with $\frac{3}{16}$ inch or more of tongue; and pieces of Ceiling with ⅛ inch or more of tongue; and pieces of Ship Lap with $\frac{3}{16}$ inch of lap will be admitted in any grade.

Pieces of Flooring, Drop Siding, Ceiling or Partition having not less than 1/16 inch tongue will be admitted in No. 2 Common. Pieces of Ship Lap having less than 5/16 inch and not less than 1/8 inch lap shall be admitted in No. 2 Common.

Standard Sizes.

In the absence of a special agreement between buyer and seller for each order, the following sizes shall be standard for all lumber and timber.

"Rough timbers sawed to standard size" means that they shall not be over 1/4 inch scant from the actual size specified. For instance, a 12x12-inch timber shall measure not less than 11¾x11¾ inch.

"Standard Dressing" means that not more than 1/4 inch shall be allowed for dressing each surface. For instance, a 12x12-inch timber, after being dressed on four sides, shall measure not less than 11½x11½ inches.

Dimension Plank and Small Timbers, When S1S1E or S4S.

Nominal Size, Inches.	Finished Size, Inches.	Nominal Size, Inches.	Finished Size, Inches.	Nominal Size, Inches.	Finished Size, Inches.
2 x 4	1⅝ x 3⅝	3 x 4	2½ x 3⅝	4 x 4	3½ x 3½
2 x 6	1⅝ x 5⅝	3 x 6	2½ x 5½	4 x 6	3½ x 5½
2 x 8	1⅝ x 7½	3 x 8	2½ x 7½	4 x 8	3½ x 7½
2 x 10	1⅝ x 9½	3 x 10	2½ x 9½	4 x 10	3½ x 9½
2 x 12	1⅝ x 11½	3 x 12	2½ x 11½	5 x 5	4½ x 4½
2 x 14	1⅝ x 13½	3 x 14	2½ x 13½	6 x 6	5½ x 5½
2 x 16	1⅝ x 15½	3 x 16	2½ x 15½		

Dimension lumber S4S 1/8 inch less in thickness and width than S1S1E shall be standard, but no objection shall be made to stock finished to the standard size for S and E.

Standard lengths are multiples of two feet, 4 to 24 feet, inclusive, but lengths shorter than 10 feet shall not be included in miscellaneous or mixed shipments except by agreement.

Dressed Finishing Lumber S1S or S2S.

Nominal Thickness, Inches.	Finished Thickness, Inches.	Nominal Widths, Inches.	Finished Widths, Inches.
1	¾	4	3½
1¼	1 1/16	5	4½
1½	1 5/16	6	5½
2	1¾	7	6½
		8	7¼
		9	8¼
		10	9¼
		11	10¼
		12	11¼
		14	13
		16	15

The foregoing widths shall also apply to stock thicker than one inch. Standard lengths are multiples of one foot.

Boards, Ship Lap, D. & M.

Nominal Size, Inches.	Common Boards S1S or S2S, Inches.	S1E or S2E, Inches.	Ship Lap Inches.	D. & M., Inches.
1 x 4	¾	3½	¾ x 3	¾ x 3¼
1 x 6	¾	5½	¾ x 5	¾ x 5⅛
1 x 8	¾	7½	¾ x 7	¾ x 7
1 x 10	¾	9½	¾ x 9	¾ x 9
1 x 12	¾	11½	¾ x 11	¾ x 11

Standard lengths are multiples of 2 feet.

Bevel Siding.

Nominal Size, Inches.	Finished Sizes — Thin Edge. Inches.	Finished Sizes — Thick Edge. Inches.	Width, Inches.
½ x 4	3/16	½	3½
½ x 5	3/16	½	4½
½ x 6	3/16	½	5½

Bevel Siding shall be made from stock S4S worked to 11/16 of an inch by 3½, 4½ and 5½ inches, and re-sawed on a bevel.

Standard lengths are multiples of one foot, from 4 to 20 feet. Five per cent. of 8 or 9 feet is allowed in mixed length shipments of "B and Better." Bevel Siding and in addition five per cent. of 6 or 7 feet in "No. 1 Common" and in addition five per cent. of 4 or 5 feet in "No. 2 Common."

The above percentage of short lengths is customary, and in the interest of conservation will be included, so far as practicable, in all shipments of mixed lengths.

Drop Siding.

No.	Nominal Size.		Finish Size.		Worked Shiplap.		
105	⅝"x6"		9/16"x4⅞"	½" rabbet			
106	⅝"x6"		9/16"x5⅛"				
105	1"x6"		¾"x4⅞"	½" rabbet			
106	1"x4"	(Worked	¾"x3¼"	Face ¼" tongue	¾"x3"	3½"	Overall
	1"x6"	D. & M.	¾"x5⅛"	Face ¼" tongue	¾"x5"	5½"	Overall
	1"x8"	" "	¾"x7"	Face ¼" tongue	¾"x7"	7½"	Overall

Standard lengths are multiples of 2 feet from 4 to 20 feet.

Five per cent. of 8 or 9 feet is allowed in mixed length shipments of "B and Better Drop Siding," and in addition five per cent. of 6 or 7 feet in "No. 1 Common" and in addition five per cent. of 4 or 5 feet in No. 2 Common.

The above percentage of short lengths is customary and in the interest of conservation will be included, so far as practicable, in all shipments of mixed lengths.

Rustic.

Nominal Size.		Finished Size.	
5/8" x 6"		9/16" x 4 7/8"	1/2" rabbet
5/8" x 8"		9/16" x 6 3/4"	1/2" rabbet
1" x 6"	Channel	3/4" x 4 7/8"	1/2" rabbet
1" x 8"	Channel	3/4" x 6 3/4"	1/2" rabbet
5/8" x 6"	V and Center	9/16" x 4 7/8"	1/2" rabbet
5/8" x 8"	V and Center	9/16" x 6 3/4"	1/2" rabbet
1" x 6"	V and Center	3/4" x 4 7/8"	1/2" rabbet
1" x 8"	V and Center	3/4" x 6 3/4"	1/2" rabbet

Standard lengths are multiples of 2 feet.

Flooring.

Nominal Size.		Finished Size.
3/4" x 3"		5/8" x 2 1/4" Face
3/4" x 4"		5/8" x 3 1/4" Face
3/4" x 6"		5/8" x 5 1/8" Face
1 " x 3"	V. G.	13/16" x 2 1/4" Face
1 " x 4"	V. G. & F. G.	13/16" x 3 1/4" Face
1 " x 6"	V. G.	13/16" x 5 1/8" Face
1 " x 6"	F. G.	3/4" x 5 1/8" Face
1 1/4" x 3"		1 1/16" x 2 1/4" Face
1 1/4" x 4"		1 1/16" x 3 1/4" Face
1 1/4" x 6"		1 1/16" x 5 1/8" Face
1 1/2" x 3"		1 5/16" x 2 1/4" Face
1 1/2" x 4"		1 5/16" x 3 1/4" Face
1 1/2" x 6"		1 5/16" x 5 1/8" Face

Two inches and thicker shall be finished according to the standard patterns as shown in cuts.

Standard lengths are multiples of one foot from 4 to 20 feet. Five per cent. of 8 or 9 foot lengths is allowed in mixed length shipments of "B and Better" and in addition five per cent. of 6 or 7 feet in C, D and No. 1 Common, and in addition five per cent. of four or five in No. 2 Common, No. 3 Common, 4 to 20 feet inclusive.

The above percentage of short lengths is customary, and in the interest of conservation will be included, so far as practicable, in all shipments of mixed lengths.

Ceiling.

Nominal Size.	Finished Size.
3/8" x 3"	5/16" x 2 1/4" Face
3/8" x 4"	5/16" x 3 1/4" Face
3/8" x 6"	5/16" x 5 1/4" Face
1/2" x 3"	7/16" x 2 1/4" Face
1/2" x 4"	7/16" x 3 1/4" Face
1/2" x 6"	7/16" x 5 1/8" Face
5/8" x 3"	9/16" x 2 1/4" Face
5/8" x 4"	9/16" x 3 1/4" Face
5/8" x 6"	9/16" x 5 1/8" Face
1" x 3"	11/16" x 2 1/4" Face
1" x 4"	11/16" x 3 1/4" Face
1" x 6"	11/16" x 5 1/8" Face

Standard lengths are multiples of one foot, from 4 to 20 feet.

Five per cent. of 8 or 9 feet is allowed in mixed length shipments of "B and Better" Ceiling and in addition five per cent. of 6 or 7 feet in No. 1 Common, and in addition five per cent. of 4 or 5 feet in No. 2 Common.

The above percentage of short lengths is customary, and in the interest of conservation will be included, so far as practicable, in all shipments of mixed lengths.

PARTITION.

Nominal Size.	Finished Size.
1" x 4"	$\frac{11}{16}$" x $3\frac{1}{4}$" Face
1" x 6"	$\frac{11}{16}$" x $5\frac{1}{8}$" Face

Standard lengths are multiples of one foot.

Same percentage of short lengths is allowed as in ceiling.

GENERAL INSTRUCTIONS ON GRADING TIMBER AND LUMBER.

No arbitrary rules for the inspection of lumber can be maintained with satisfaction. The combinations and evaluations of defects are numerous and classification in grading lumber must be left to practical common sense. The general features of these classes are given by the following description of grades.

All lumber is graded with special reference to its suitability for the use intended.

With this in view each piece is considered and its grade determined by its general character, including the sum of all its defects.

Inspection of lumber is not an exact science and a reasonable variation of opinion between inspectors should be recognized; therefore, a variation of not more than 5 per cent. upon reinspection should not disturb the original inspection.

The enumerated defects herein described in any grade are intended to be descriptive of the coarsest piece such grades may contain.

Equivalent means equal, and in construing and applying these rules, the defects allowed are understood to be equivalent in damaging effect to those mentioned applying to stock under consideration.

In case of a piece of lumber which lies so close to the boundary line between two grades that there is doubt as to which grade it belongs in, it shall be given the lower grade.

A shipment of any grade must consist of a fair average of that grade and shall not include an unfair proportion of the better or poorer pieces that would pass in that grade. A shipment of mixed widths shall contain a fair assortment of each width. A shipment of mixed lengths shall contain a fair assortment of each length.

Defects in lumber are to be considered in connection with the size of the piece, and for this reason wider and longer pieces will carry more defects than smaller pieces in the same grade. Defects in flooring, ceiling, partition, casing and base, drop siding and rustic are based on a piece 4 inches wide and 12 feet long, except where otherwise specified.

Lumber must be accepted on grade in the form in which it was shipped. Any subsequent change in manufacture or condition will prohibit a re-inspection for the adjustment of claims, except with the consent of all parties interested.

What is known as "Yard Lumber," such as Dimension, Common Boards and Finish, etc., is graded from the face side, which is the best side, except that lumber which is dressed one side only is graded from the dressed side.

Factory lumber, which is used for the manufacture of doors, sash, etc., and must show both sides, is always graded from the poorer side. The grade is determined by the quantity of suitable cuttings obtainable in each piece.

All dressed lumber shall be measured and sold at the full size of rough material used in its manufacture.

All lumber one inch or less in thickness shall be counted as one inch thick.

The term "Vertical Grain" is here used as synonymous with edge grain, rift sawed or quarter sawed. The term "Flat Grain" is synonymous with slash grain or plain sawed.

Definitions Relating to Select Structural Grade for Bridge and Trestle Timbers, Douglas Fir and Southern Yellow Pine Specifications.

Annual Ring.

Each annual ring is composed of two distinct types of wood structure, i. e., the porous, light colored and lightweight springwood formed during the first part of the growing season and the hard, dense and darker-colored summerwood formed during the latter part of the growing season.

Springwood.

The inner part of the annual ring formed in the earlier part of the season, not necessarily in the spring and often containing vessels or pores.

Summerwood.

The outer part of the annual ring formed later in the season, not necessarily in the summer, being usually dense in structure, darker in color and without conspicuous pores.

Measurement of Knots.

In Beams, the diameter of a knot on the narrow or horizontal face shall be taken as its projection on a line perpendicular to the edge of the timber. On the wide or vertical face, the smallest dimension of a knot is to be taken as its diameter.

In Columns, the diameter of a knot on any face shall be taken as its projection on a line perpendicular to the edge of the timber.

Select Structural Grade for Bridge and Trestle Timber, Douglas Fir and Southern Yellow Pine Specifications.

General Requirements.

(a) Shall contain only Dense Douglas Fir or Southern Yellow Pine timbers.

Dense timber of the above kinds shall show on either one end or the other an average of at least six annual rings per inch, or eighteen rings in three inches as measured over the third, fourth and fifth inches of a radial line from the pith and at least 33⅓ per cent. summerwood for girders not exceeding 20 inches in height, and for columns, 16 inches square or less. For larger timbers the inspection shall be made over the central three inches on the longest radial line from the pith to the corner of the piece. Wide ringed material excluded by the above will be accepted, provided the amount of summerwood as above measured shall be at least 50 per cent.

The contrast in color between summerwood and springwood shall be sharp, and the summerwood shall be dark in color, except in pieces having considerably above the minimum requirement for summerwood.

In cases where timbers do not contain the pith, and it is impossible to locate it with any degree of accuracy, the same inspection shall be made over three inches on an approximate radial line beginning at the edge nearest the pith in timbers over three inches in thickness and on the second inch (on the piece) nearest to the pith in timbers three inches or less in thickness.

In dimension material containing the pith but not a five-inch radial line, which is less than two by eight inches in section or less than eight inches on the cross-section, the inspection shall apply to the second inch from the pith. In larger material that does not show a five-inch radial line, the inspection shall apply to the three inches farthest from the pith.

The radial line chosen shall be representative. In case of a disagreement between purchaser and seller as to what is a representative radial line, the average summerwood and number of rings shall be the average of the two radial lines chosen.

(b) Shall consist of lumber well manufactured, square edge and sawed standard size; solid and free from defects, such as ring shakes and injurious diagonal grain; loose or rotten knots; knots in groups; decay; pitch pockets over six inches long or ⅜ inch wide, or other defects that will materially impair its strength.

(c) Occasional variation in sawing not to exceed ¼-inch scant at time of manufacture allowed.

(d) When timbers 4 by 4 inches and larger are ordered sized, they will be ½ inch less than nominal size, either S1S1E or S4S, unless otherwise specified.

Stringers, Girders and Deep Joists.

Shall show not less than 85 per cent. of heart on each of the four sides, measured across the sides anywhere in the length of the piece.

Shall not have in volume 1 and 2, knots aggregating greater in diameter than one-fourth the width of the face in which they occur, with a maximum for any one knot of 1½ inches in diameter.

Shall not have in volume 3, knots aggregating larger than one-third the width of the face in which they occur, with a maximum for any one

knot of 3 inches in diameter. Knots within the center half of the span shall not exceed in the aggregate the width of the face in which they occur.

Shall not permit diagonal grain in volumes 1 or 2 with a slope greater than one in twenty.

When stringers are of two or more span length, they shall be considered as two or more separate pieces and the above restrictions applied to each span length.

The inspector shall place his stamp on the edge of the stringer to be placed up in service.

Cap and Sills.

Shall show 85 per cent. of heart on each of the four sides, measured across the sides anywhere in the length of the piece, and shall be free from knots aggregating larger than one-fourth the width of the face in which they occur with maximum for any one knot of 3 inches in diameter. Knots shall not be in groups.

Posts.

Shall show not less than 85 per cent. of heart on each of the four sides, measured across the face anywhere in the length of the piece, and shall be free from knots larger than one-fourth the width of the face in which they occur, with a maximum of 3 inches in diameter. Knots shall not be in groups.

Longitudinal Struts or Girts.

Shall show all heart on one face; the other face and two sides shall show not less than 85 per cent. of heart, measured across the face or side anywhere in the length of the piece. Shall be free from knots over 2 inches in diameter.

Longitudinal Cross Braces, Sash Braces and Sway Braces.

Shall show not less than 85 per cent. of heart on two faces and shall be free from knots larger than one-third the width of the face in which they occur, with a maximum of 2 inches in diameter.

Branding.

The inspector shall brand each timber which conforms to the above requirements, "Select Structural" (Douglas Fir or Yellow Pine as the case may be).

Commercial Timber and Lumber Grades.

Timber.

Selected Common.

Selected Common shall be sound, strong timber, well manufactured and free from defects that materially impair its strength. Must be suitable for high-class construction purposes, free from shake, splits, loose or rotten knots. Will allow sound and tight knots, if not in clusters and which in no case shall exceed in diameter one-sixth the width of the face in which such knots occur up to and including 12x12-inch; and further

providing that such sound and tight knots in 14x14-inch and larger shall in no case exceed 2½ inches in diameter.

The select common grade also will allow occasional variation in sawing; tight pitch pockets, not over six inches in length, wane not to exceed one inch on one corner and not exceeding one-sixth the length of the piece.

White sap or a slight amount of sound stained sap on the back shall not be considered a defect in this grade.

No. 1 Common.

No. 1 Common Timber 6x10 inches and larger shall be sound stock well manufactured and free from defects that will materially weaken the piece. Occasional slight variation in sawing allowed.

Ten by ten-inch timbers may have a 2-inch wane on one corner or the equivalent on two or more corners, checks and season checks not extending over one-eighth the length of the piece. Smaller and larger timbers may have wane in proportion. In addition will allow large sound and tight knots, which approximately should not be more than one-fourth the width in diameter of any one side in which they may appear, spike knots, stained sap one-third the width and slight streak of heart stain extending not more than one-fourth the length of the piece.

No. 2 Common.

No. 2 Common Timbers will admit large, loose or rotten knots; a 10x10-inch may have a 3-inch wane on one corner or the equivalent on two or more corners, larger and smaller sizes in proportion; shake or rot that does not impair its utility for temporary work.

Dimension Plank, Joists, Scantling and Small Timbers.

Selected Common.

Selected Common shall be sound, strong lumber well manufactured and free from defects that materially impair the strength. Must be suitable for high-class construction purposes and free from shake, loose or rotten knots.

Will allow occasional variation in sawing, sound and tight, small and standard knots and tight pitch pockets not over 6 inches in length.

Twelve inches and wider may contain, in addition to the above, a couple of large knots not to exceed 2 inches in diameter when well placed, a slight amount of sap admissible.

No. 1 Common.

No. 1 Common must be sound stock, well manufactured and suitable for all ordinary construction purposes without waste and must be sound and tight-knotted stock.

Will admit knots which in a 2x4 or 3x4 piece may be approximately 1½ inches; in a 2x6-inch or 3x6-inch piece, 2 inches; in a 2x8-inch or 3x8-inch or 2x10-inch or 3x10-inch piece, 2½ inches; and one-fourth the width of the piece in 12 inches and wider; spike knots that do not mate-

rially weaken the piece; wane not over one-fourth the thickness of the piece 1 inch wide on face up to 6 inches, and 1½ inches wide on face of 8 inches and wider, extending not more than one-third the length of the piece or a proportionate amount for a shorter distance on both edges, in any case one side and two edges should provide a good nailing surface, and in no case shall wane extend over one-half the side of the piece.

Pith knots or small defective knots which do not weaken the piece more than the knots above allowed are admitted, solid pitch, pitch pockets, sap stain, a limited number of worm holes well scattered, limited torn grain, seasoning checks, splits in ends, not exceeding in length the width of the piece, firm red heart, heart shakes that do not go through.

May contain crook of 1½-inch in 2x4—16 feet, and ⅛ inch less in each additional 2 inches in width up to and including 2x12—16 feet. Length longer or shorter than 16 feet of No. 1 Common Dimension may contain crook in proportion to the above.

No. 2 Common.

This grade shall consist of lumber suitable for a cheaper class of construction than No. 1 Common.

Will admit large, coarse sound knots, which in a 2x4 and 3x4-inch piece should not be larger than 2½ inches in diameter; in 2x6 or 2x8 or 3x6 or 3x8-inch pieces, 3 inches, and in 2x10 or 3x10 or wider pieces one-third the width of the piece in diameter, spike knots, smaller, loose, hollow or rotten knots that do not weaken the piece more than the knots aforesaid, worm holes well scattered, large pitch pockets, rotten streaks, small amount of fine shake, split not to exceed one-quarter the length of the piece, heart and sap stains in any amount, decayed sap, wane if leaving a fair nailing surface.

May contain crook of 2 inches in 2x4—16 feet, and ⅛ inch less in each additional 2 inches in width up to and including 2x12—16 feet. Length shorter or longer than 16 feet may contain crook in proportion to the above.

Miscut 2-inch Common which does not fall below 1½ inches in thickness or ⅛ inch scant in width from standard size, shall be admitted in No. 2 Common, provided such pieces are in all other respects as good as No. 1 Common at point of miscut.

A very serious combination of above defects must not be permitted in any one piece.

No. 3 Common.

No. 3 Common will include all pieces falling below No. 2 Common which are sound enough to use for cheap building material by wasting 25 per cent. of each piece of one-third of number of pieces in any one item of a shipment but it must not be more than ½ inch scant of standard finished width nor ⅜ inch scant of standard finished thickness. This grade will admit a greater degree of all the imperfections allowed in No. 1 and No. 2 Common, but shall not admit useless culls.

Boards, Ship Lap and D & M.

Selected Common.

Selected Common shall be square edged, well manufactured. Will admit sound tight knots not over 1 inch in diameter in 4-inch and 6-inch, not over 1½ inches diameter in 8-inch, medium sized tight pitch pockets not over 6 inches in length, two pith knots, the equivalent of one split not to exceed in length the width of the piece, torn grain, pitch pockets, slight shake, sap stain, seasoning checks, firm red heart, small amount of slightly stained sap. These boards must be of a sound, strong character.

No. 1 Common.

No. 1 Common will admit any two of the following or their equivalent of combined defects:

Sound and tight knots approximately 1½ inches in diameter in 4 and 6-inch; 2 inches in diameter in 8 and 10-inch; 2½ inches in 12-inch and not over 3 inches in diameter in widths over 12 inches.

Pitch pockets, seasoning checks, one straight split not longer than the width of the piece, sap stain, slight streak of heart stain, pith knots, torn grain, slight shake, firm red heart, wane ½ inch deep on edge not exceeding 1 inch in width on face and extending not over one-third the length of the piece, a limited number of pin worm holes well scattered.

These boards must be firm, sound and suitable for use in ordinary construction except finishing purposes without waste.

No. 1 Common Ship Lap or D & M or Barn Siding shall be graded by rules governing No. 1 Common Boards, except as to wane which shall not be so deep as to extend into the tongue or one-half the thickness of the top lip on the groove in D & M, or over one-half the thickness of the lap in Ship Lap on the face side; pieces of Ship Lap with 5/16 inch of lap will be admitted in any grade.

No. 2 Common.

No. 2 Common will admit large coarse knots not necessarily sound, approximately 2 inches in diameter in 4 and 6-inch stock; 2½ inches in 8 and 10-inch and one-third the width of the piece in 12-inch and wider, spike knots, solid heart or sap stain, solid pitch or pitch pockets, a limited number of well scattered worm holes, splits one-fourth the length of the piece. Small amount of fine shake, wane 2 inches wide if it does not extend into the opposite face, or through heart shakes over one-half the piece or through rotten streaks when firm, ½ inch wide over one-fourth the length of the piece or its equivalent of unsound red heart or combination of defects equivalent to the above but a serious combination of above defects in any one piece not permitted.

A knot hole 2 inches in diameter will be admitted provided the piece is otherwise as good as No. 1 Common.

Miscut 1-inch Common Boards which do not fall below ¾ inch in thickness shall be admitted in No. 2 Common, provided the grade of such thin stock is otherwise as good as No. 1 Common.

No. 3 Common.

No. 3 Common will admit of stock below the grade of No. 2 Common that is suitable for cheap sheathing. The general appearance is coarse. It will admit large coarse knots without restrictions as to size, loose knots, unsound knots, knot holes, pitch pockets, solid pitch, very wormy pieces, shake, heart or sap stain, decayed sap, decayed streaks, well scattered small rotten spots, split, blue sap, wane but a serious combination of above defects in any one piece not permitted. It should cut 75 per cent. of lumber as sound as No. 2 Common.

No. 4 Common.

No. 4 Common shall include all pieces that fall below the grade of No. 3 Common, excluding such pieces as will not be held in place by nailing. After wasting one-fourth the length of the piece by cutting into two or three pieces.

The predominating defect characterizing this grade is red rot. Other defects are numerous large worm holes, several knot holes, or pieces that are extremely coarse knotted, waney, shaky or badly split, extremely cross-checked.

No. 5 Common.

No. 5 Common is the lowest grade and admits of all defects known in lumber provided the piece is strong enough to hold together when carefully handled.

Thick Common Lumber.

Common lumber, 1¼ inches and thicker, shall be graded the same as 1-inch lumber.

Rough Stock for Finish.

Finish must be evenly manufactured and shall embrace all sizes from 1 to 2 inches inclusive in thickness by 3 inches and over in width.

One, 1¼ and 1½-inch finishing lumber unless otherwise ordered shall measure when dry, not more than 1/16 inch scant in thickness and 2-inch not more than ⅛ inch scant in thickness when seasoned.

Stock width shipments of "C" and "Better," either rough or dressed on one or two sides, shall be accepted as standard where not more than 20 per cent. of any shipment is ¼ inch scant on 8-inch widths and under; ⅜ inch scant on 9 or 10-inch; and ½ inch scant on 11 and 12-inch and wider when seasoned; pieces narrower than the above and pieces in excess of 20 per cent. of the shipment that are of the minimum measurement given, should be measured as of the next lower standard width and not reduced in grade.

Standard lengths are 8 to 20 feet; and in shipments of mixed lengths, 5 per cent. of 8 feet in grade of "C" and "Better" shall be admitted. The above percentage of short lengths is customary and in the interest of conservation will be included as far as practicable in all shipments of mixed lengths.

Wane and other defects that will dress out in working standard sizes are admissible.

Finishing lumber ordered rough if thicker than count thickness for dry or green stock, may be dressed to such count thickness, and when so dressed, shall be considered as rough.

Rough finish shall be graded on the best side, but the reverse side must not be more than one grade lower.

Subject to the foregoing provisions, Rough Finishing Lumber shall be graded according to the rules applying to Dressed Finishing Lumber.

When like grade on both faces is required, special contract must be made.

Dressed Finishing Lumber.

Selected Flat Grain.

Selected Flat Grain shall be finishing lumber free from all sap or defects on face and edges and shall be selected for beauty and character of grain.

"A" Finishing inch, 1¼, 1½ and 2-inch dressed one or two sides up to and including 12 inches in width, must show one face practically clear of all defects, except that it may have such wane as would dress off if surfaced four sides; 13-inch and wider "A" Finishing will admit two small defects or their equivalent. "B" Finishing, inch, 1¼, 1½ and 2-inch dressed one or two sides, up to and including 10 inches in width in addition to the equivalent of one split in end which should not exceed in length the width of the piece, will admit any two of the following or their equivalent of combined defects; slightly torn grain, three pin knots, one standard knot, three small pitch pockets, one standard pitch pocket, one standard pitch streak, 5 per cent. of sap stain or firm red heart; wane not to exceed 1 inch in width, ¼ inch in depth and one-sixth the length of the piece, small seasoning checks.

Eleven-inch and wider "B" Finishing will admit three of the above defects or their equivalent, but sap stain or firm red heart shall not exceed 10 per cent.

"C" Finishing up to and including 10-inch in width will admit in addition to the equivalent of one split in end which should not exceed in length the width of the piece, any two of the following, or their equivalent of combined defects: 25 per cent. of sap stain, 25 per cent. firm red heart, two standard pitch streaks, medium torn grain in three places, slight shake, seasoning checks that do not show an opening through, two standard pitch pockets, six small pitch pockets, two standard knots, six pin knots, wane 1 inch in width, ½ inch in depth and one-third the length of the piece. Defective dressing or slight skips in dressing will also be allowed that do not prevent its use as finish without waste. Eleven-inch and 12-inch "C" Finishing will admit one additional defects or its equivalent. Pieces wider than 12 inches will admit two additonal defects to those admitted in 10-inch or their equivalent, except sap stain which shall not be increased.

Selected Flat Grain.

Pieces otherwise as good as "B" will admit of twenty worm holes.

Special Finish.

In case both sides are desired, "A," "B" or "C" grade, or free from all defects, special contract must be made. Defective dressing or slight skips in dressing on the reverse side of Finishing are admissible.

Moulded Casing, Base, Window and Door Jambs.

Moulded Casing and Base shall be worked to ¾ inch thick as per established patterns.

Window and Door Jambs are to be dressed, rabbeted and plowed as ordered.

Grades A, B and C.

"A" Grade must be practically free from defects on the face side and well manufactured.

"B" Grade shall admit the same defects as are admissible in the same widths of "B" Finishing except wane.

"C" Grade shall admit the same defects as are admissible in the same widths of "C" Finishing except wane.

Moulding.

"B and Better" Moulding. One-third of any item may contain any one of the following defects or its equivalent: One pin knot, small pitch pockets, pitch 1 inch wide, 6 inches long, three pin worm holes, slight defects in dressing.

Standard lengths; 8 feet and longer, and in shipments of mixed lengths 5 per cent. of 6 or 7 feet shall be admitted, even though the number of feet of each length be specifically stated.

Drop Siding.

Defects named in Drop Siding are based upon a piece manufactured from 1x6—12 feet, and pieces larger or smaller than this will take a greater or lesser number of defects, proportioned to their size on this basis.

The amount of crook permissible in No. 1 Common and Better Drop Siding may be as follows:

Sixteen-foot lengths as a basis for 4-inch widths, 3 -inch crook.

Sixteen-foot lengths as a basis for 6-inch widths, 2½-inch crook.

Lengths longer or shorter than 16 feet may have a proportional amount of crook.

In all grades of Drop Siding wane on the reverse side, not exceeding one-third the width and one-sixth the length of any piece is admissible, providing the wane does not extend into the tongue.

"A" Drop Siding.

"A" Drop Siding must be practically free from defects on the face side and well manufactured.

Slight roughness in dressing admissible.

A piece 14 feet or longer may have one defect located 4 feet or more from the end that can be cut out by wasting not more than 1½ inches of the length, provided balance of piece be practically free from other defects.

"B" Drop Siding.

"B" Drop Siding will admit any two of the following defects: Medium torn grain, three pin knots, one standard knot, 15 per cent. sap stain, 15 per cent. firm red heart, small seasoning checks, six pin worm holes or any one of the above defects combined with either three small pitch pockets or one small pitch streak.

A piece that is otherwise as good as "B" grade may have a defect that can be cut out by wasting not more than 2½ inches in the length of the piece, providing the defect is 4 feet or more from the end.

No. 1 Drop Siding.

No. 1 Common Drop Siding will admit numerous small or several medium or one large pitch pocket, one standard pitch streak and in addition sound knots not over one-half the width of the piece in the rough, a couple of small knot holes, pin worm holes or a few well scattered grub-worm holes, sap stain, firm red heart, slight shake, heavy torn grain, seasoning checks that do not show an opening through, defects in manufacturing that will lay without waste. A very serious combination of above defects not permissible in any one piece.

Pieces otherwise as good as "B" Drop Siding may have one defect (like a knot hole) that can be cut out by wasting 2½ inches of the length of the piece, provided both pieces are 16 inches or over in length after cutting out such defects.

No. 2 Common Drop Siding.

No. 2 Common Drop Siding admits of all pieces not as good as No. 1 Common that can be used without waste of more than one-fourth the length of any one piece.

Bevel Siding.

Bevel Siding shall be graded according to the rules for Drop Siding and will admit in addition slight imperfections on the thin edge, which will be covered by the lap when laid 2½ and 4½ inches to the weather.

Rustic Siding.

Rustic Siding shall be graded according to the rules for Drop Siding.

Flooring.

Special.

Defects named in Flooring are based upon a piece manufactured from 1x4—12 feet long, and pieces larger or smaller than this will take a greater or lesser number of defects, proportioned to their size on this basis, except that standard knots shall not exceed 1¼ inches in diameter in 3-inch flooring.

The amount of crook permissible in No. 1 Common and Better Flooring may be as follows:

Sixteen-foot lengths as a basis for 3-inch widths, 3½-inch crook.

Sixteen-foot lengths as a basis for 4-inch widths, 3 -inch crook.

Sixteen-foot lengths as a basis for 6-inch widths, 2½-inch crook.

Lengths longer or shorter than 16 feet may have a proportionate amount of crook.

Standard Matched Flooring to be surfaced two sides with scored back.

Center Matched Flooring (S2S and C. M.) shall be required to come up to grade on one side only, and the defects admissible on the reverse side of standard match shall be allowed.

GRADES A, B, C, D, AND NO. 1 COMMON, EDGE OR VERTICAL GRAIN.

GRADES A, B, C, D, NO. 1 COMMON, NO. 2 COMMON, NO. 3 COMMON OR NO. 3 SHEATHING, FLAT GRAIN.

Grade "A" Edge Grain Flooring.

Admits no piece in which angle of the grain exceeds 45° from vertical at any point. This grade shall be well milled on face, must have perfect edges and be practically free from all defects on the face side. Bright sap showing not more than one-third of face half the length of piece will be admitted.

Grade "B" Edge Grain Flooring.

Admits no piece in which angle of the grain exceeds 45° from vertical at any point. This grade will admit any two of the following or their equivalent of combined defects: Five per cent. sap stain, 15 per cent. firm red heart, three pin knots, one standard pitch streak, slight torn grain, small seasoning checks.

Grade "C" Edge or Vertical Grain Flooring.

Admits no piece in which angle of the grain exceeds 45° from vertical at any point. This grade will admit any two of the following defects or their equivalent or combined defects. Fifteen per cent. sap stain, 25 per cent. firm red heart, six pin knots, two standard knots, small pitch pockets, two standard pitch pockets, two standard pitch streaks, twelve pin worm holes, slight shake that does not go through, seasoning checks that do not show an opening through, medium torn grain or other machine defects that will lay without waste.

A piece 12 feet or longer otherwise as good as "B" may have a defect that can be cut out and the piece laid with a loss of not more than 2½ inches in its length, providing the defect is 4 feet or more from the end of the piece.

Grade "D" Edge or Vertical Grain Flooring.

Admits no piece in which angle of the grain exceeds 45° from vertical at any point. This grade will admit the following defects or their equivalent of combined defects. Sap stain, firm red hearts, sound knots not over

one-half the cross-section of the piece in the rough and any one point throughout its length, three pith knots, pitch, pitch pockets, a limited number of pin worm holes well scattered, shake that does not show an opening through, loosened or heavy torn grain or other machine defects that lay without waste.

Pieces otherwise as good as "B" Flooring may have one defect (like a knot hole) that can be cut out by wasting 20 inches of the length of the piece, provided both pieces are 16 inches or over in length after cutting out such defects.

It is generally understood that this grade will admit such defects or combination of defects as will not impair its utility for cheap floors.

No. 1 Common Flooring is the combined grade of C and D Flooring and will admit all pieces that will not grade "B" and are better than No. 2 Common Flat Grain Flooring.

Flat Grain Flooring shall take the same inspection as Edge or Vertical Grain, except as to requirement of angle of the grain.

No. 2 Common Flooring.

Admits all pieces that will not grade as good as "D" Flooring that can be used for cheap floors without waste of more than one-fourth the length of any one piece.

Pieces of flooring having not less than $\frac{1}{8}$ inch tongue will be admitted in No. 2 Common.

No. 3 Common on No. 3 Sheathing.

Admits all pieces that cannot be used as No. 2 Common Flooring but are still available as cheap sheathing or lathing without waste of more than one-fourth the length of any one piece.

Ceiling.

Defects in Ceiling are based upon a piece manufactured from 1x4—12 feet long, and pieces larger or smaller than this will take a greater or lesser number of defects, proportionate to their size on this basis.

The amount of crook permissible in No. 1 Common and Better Ceiling may be as follows:

Sixteen-foot lengths as a basis for 3-inch widths, 3½-inch crook.
Sixteen-foot lengths as a basis for 4-inch widths, 3 -inch crook.
Sixteen-foot lengths as a basis for 6-inch widths, 2½-inch crook.

Lengths longer or shorter than 16 feet may have a proportionate amount of crook. In all grades of Ceiling wane on the reverse side, not exceeding one-third the width and one-sixth the length of any piece, is admissible providing the wane does not extend into the tongue.

Ceiling may be specified either as Edge or Vertical Grain or Flat Grain. The inspection will be the same for either kind.

"A" Ceiling.

"A" Ceiling must be practically free from defects on the face side, well manufactured, will admit of slight roughness in dressing, through close pitch pockets, each not to exceed 2 inches in length, or one sound and tight smooth pin knot, or the equivalent of combined defects.

"B" Ceiling.

"B" Ceiling will admit of any two of the following defects or their equivalent of combined defects: Slight torn grain, three pin knots, two small or one standard knot, three small pitch pockets, any two of which may be open, one standard pitch pocket, one small pitch streak, small seasoning checks, 15 per cent. sap stain, 15 per cent. firm red heart, six pin worm holes.

A piece otherwise as good as No. 2 may have a defect that can be cut out and the piece laid with a waste of not more than 2½ inches in length, providing the defect is 4 feet or more from the end of the piece.

No. 1 Common Ceiling.

No. 1 Common Ceiling will admit the following defects or their equivalent of combined defects: Heavy torn grain, sound knots not over one-half the cross-section of the piece in the rough, pitch, pitch pockets, seasoning checks that do not show an opening through, a sap stain, firm red heart, slight shake, defects in manufacture that will lay without waste, a limited number of pin worm holes well scattered.

Pieces otherwise as good as "B" Ceiling may have one defect (like a knot hole) that can be cut by wasting 2½ inches of the length of the piece, providing both pieces are 16 inches or over in length after cutting out such defects.

No. 2 Common Ceiling.

No. 2 Common Ceiling admits of all pieces not as good as No. 1 Common that can be used without waste of more than one-fourth the length of any one piece.

Pieces of Ceiling having not less than $\frac{3}{16}$ inch tongue, will be admitted in No. 2 Common.

Partition.

Grades "A," "B," No. 1 Common and No. 2 Common. Partition shall be graded according to Ceiling rules and must meet the requirements of the specified grades on the face side only, but the reverse side shall not be more than one grade lower, and shall not cause waste in No. 1 Common and Better.

CLASSIFICATION OF THE USES OF LUMBER.

1. Bridge and Construction Timber.

A. Combination and Howe Truss Spans.

1. Compression members.
2. Tension members.
3. Diagonals subject to reversal of stress.
4. Floor beams.
5. Stringers.
6. Ties.
7. Guard timbers.
8. Railing.
9. Stiffeners.
10. Splices.
11. Nailing strips.
12. Grillage.
13. Deck plank.
14. Bridging.

B. Pile and Frame Trestles.

1. Piles.
2. Sills and mud sills.
3. Posts.
4. Caps.
5. Cross bracing.
6. Sash bracing.
7. Longitudinal bracing.
8. Girts.
9. End plank.
10. Stringers.
11. Ties.
12. Guard timbers.
13. Planking for ballasted deck.
14. Railing.

C. Falsework.

1. Piles.
2. Sills and mud sills.
3. Posts.
4. Caps.
5. Stringers.
6. Truss timbers.
7. Centering.
8. Lagging.
9. Bracing.
10. Wedges.
11. Scaffolding.

D. Concrete Forms.

1. Dimension lumber.
2. D. & M. planks.
3. Bracing.

E. Tanks and Supports.

1. Piles.
2. Sills.
3. Posts.
4. Caps.
5. Bracing.
6. Joists.
7. D. & M. flooring.
8. Staves.
9. Rafters.
10. Roof.
11. Ladders, etc.
12. Frost-box material.

F. Docks and Wharves.

1. Piles.
2. Timber sheet piling.
3. Timber in cribs.
4. Caps.
5. Stringers.
6. Bracing.
7. Guard timber.
8. Ties.
9. Plank decking.
10. Mooring posts.
11. Fenders and wales.
12. Warehouse. (See II.)

G. Coaling Stations and Ore Stations.

1. Piles.
2. Sills and mud sills.
3. Posts.
4. Caps.
5. Bracing.
6. Stringers.
7. Joists.
8. Bin lining.
9. Rafters.
10. Flooring.
11. Chutes.
12. Decking.
13. Coal pockets or bins.
14. Roofing.

2. Frame Buildings.

A. Station Buildings, Passenger, Freight, Platform Shelters.

1. Piles.
2. Caps.
3. Sills.
4. Posts.
5. Stringers.
6. Joists.
7. Bridging.
8. Sub-flooring.
9. Finish flooring.
   (a) Pine.
   (b) Fir.
   (c) Maple or oak.
10. Studding and plates.

11. Sheathing.
12. Furring.
13. Siding.
14. Ceiling.
15. Lath.
16. Truss timbers.
17. Purlins.
18. Rafters.
19. Roof boards.
20. Shingles.
21. Door and window frames.
22. Outside finish lumber.
23. Inside finish lumber.
24. Millwork.
    - (a) Mouldings.
    - (b) Stairs.
    - (c) Doors.
    - (d) Windows.
25. Partitions.
26. Shelving.

B. Engine House.

1. Piling.
2. Caps.
3. Sills.
4. Posts.
5. Stringers.
6. Joists.
7. Bridging.
8. Flooring.
9. Pit timbers.
10. Studding.
11. Sheathing.
12. Furring.
13. Siding.
14. Ceiling.
15. Lath.
16. Truss timbers.
17. Purlins.
18. Rafters.
19. Roof boards.
20. Shingles.
21. Door and window frames.
22. Outside finish lumber.
23. Inside finish lumber.
24. Millwork.
25. Sleepers.

C. Machine Shops.

1. Piling.
2. Caps.
3. Sills.
4. Posts.
5. Stringers.
6. Joists.
7. Bridging.
8. Flooring.
9. Studding.
10. Sheathing.
11. Furring.
12. Siding.
13. Ceiling.
14. Lath.
15. Truss timbers.
16. Purlins.
17. Rafters.
18. Roof boards.
19. Shingles.
20. Door and window frames.
21. Outside finish lumber.
22. Inside finish lumber.
23. Millwork.
24. Sleepers.

D. Section Houses.

1. Posts.
2. Sills.
3. Caps.
4. Stringers.
5. Joists.
6. Bridging.
7. Sub-flooring.
8. Finish flooring.
9. Studding and plates.
10. Sheathing.
11. Furring.
12. Siding.
13. Ceiling.
14. Lath.
15. Rafters.
16. Roof boards.
17. Shingles.
18. Door and window frames.
19. Outside finish lumber.

20. Inside finish lumber.
21. Millwork.

E. Miscellaneous Small Buildings.
1. Posts.
2. Sills.
3. Caps.
4. Stringers.
5. Joists.
6. Bridging.
7. Sub-flooring.
8. Finish flooring.
9. Studding and plates.
10. Sheathing.
11. Furring.
12. Siding.
13. Ceiling.
14. Lath.
15. Rafters.
16. Roof boards.
17. Shingles.
18. Door and window frames.
19. Outside finish lumber.
20. Inside finish lumber.
21. Millwork.

F. Warehouses.
1. Piling.
2. Caps.
3. Sills.
4. Posts.
5. Stringers.
6. Joists.
7. Bridging.
8. Sub-flooring.
9. Finish flooring.
10. Studding and plates.
11. Sheathing.
12. Furring.
13. Siding.
14. Ceiling.
15. Lath.
16. Truss timbers.
17. Purlins.
18. Rafters.
19. Roof boards.
20. Shingles.
21. Door and window frames.
22. Outside finish lumber.
23. Inside finish lumber.
24. Millwork.
25. Sleepers.

G. Ice Houses.
1. Piling.
2. Sills.
3. Caps.
4. Posts.
5. Stringers.
6. Joists.
7. Bridging.
8. Sleepers.
9. Sub-flooring.
10. Finish flooring.
11. Studding.
12. Sheathing.
13. Furring.
14. Siding.
15. Ceiling.
16. Lath.
17. Truss timbers.
18. Purlins.
19. Rafters.
20. Roof boards.
21. Shingles.
22. Door and window frames.
23. Outside finish lumber.
24. Inside finish lumber.
25. Millwork.

3. Ties.

A. Track Ties.
B. Switch Ties.

4. Miscellaneous Roadway Material.

A. Crossing Plank.
B. Platforms.
1. Posts.
2. Caps.
3. Sills.
4. Stringers.
5. Joists.
6. Bridging.

7. Planking.
8. Railing.
9. Steps.
10. Skids.

C. Stock Guards.

1. Posts.
2. Ties.
3. Wing fences and aprons.
4. Slats.
5. Fillers.

D. Signs and Posts.

1. Posts.
2. Bracing.
3. Sign boards.
4. Moulding.

E. Fencing, Including Snow Fence.

1. Posts.
2. Bracing.
3. Stringers.
4. Fence boards.
5. Gate material.
6. Stakes.

F. Culverts and Drains.

1. Sills.
2. Bracing.
3. Timbers.
4. Planking.
5. Grillage.

G. Stock Pens.

1. Posts.
2. Sills.
3. Fencing.
4. Studding.
5. Sheathing.
6. Rafters.
7. Roof boards.
8. Shingles.
9. Outside finish lumber.

H. Poles.

I. Conduits.

J. Bumping Blocks.

K. Cross-arms.

Respectfully submitted,

Committee on Wooden Bridges and Trestles.

REPORT OF COMMITTEE XIII—ON WATER SERVICE.

A. F. DORLEY, *Chairman;*
J. T. ANDREWS,
R. C. BARDWELL,
J. M. BROWN,
C. BUCHOLTZ,
E. M. GRIME,
W. C. HARVEY,
J. L. CAMPBELL, *Vice-Chairman;*
C. R. KNOWLES,
E. G. LANE,
E. H. OLSON,
W. A. PARKER,
H. N. RODENBAUGH,
R. W. WILLIS,

Committee.

To the American Railway Engineering Association:

Your Committee on Water Service presents below its report to the Twentieth Annual Convention.

The Committee was instructed by the Board of Direction to make a study and report during the year on the following subjects:

(1) Make critical examination of the subject-matter in the Manual and submit definite recommendations for changes.

(2) Study regulations of Federal or State authorities relating to supply of drinking water on trains and premises of railroads.

(3) Make final report on design of impounding reservoirs and conditions under which they are economical.

(4) Report upon plans and specifications for typical water station layouts.

(5) Report on suitable type of water meters for use in railroad water service, methods followed in testing and reading meters, and checking consumption of city water.

(6) Study of locomotive flue failures which may be due to improper water conditions and report upon methods of treatment to correct such conditions.

(7) Continue the study of preparation of questions and answers for the examination of men responsible for the care and operation of pumping stations.

COMMITTEE MEETINGS.

In addition to the various meetings of the Sub-Committees, three meetings of the General Committee were held in the office of the Association at Chicago.

SUB-COMMITTEES.

The following Sub-Committees were appointed to make the necessary investigations and prepare reports on the several subjects assigned, the number of the Sub-Committee in each case being the same as the number of the subject in its charge:

Subject (1) J. L. Campbell, Chairman; E. H. Olson.

Subject (2) R. C. Bardwell.

Subject (3) E. H. Olson, Chairman; J. M. Brown, E. M. Grime, C. R. Knowles, R. W. Willis.

Subject (4) C. R. Knowles, Chairman; J. T. Andrews, W. A. Parker, J. M. Brown.

Subject (5) C. R. Knowles, Chairman; R. C. Bardwell, E. M. Grime, C. Bucholtz.

Subject (6) R. C. Bardwell, Chairman; C. R. Knowles, E. G. Lane.

Subject (7) W. C. Harvey, Chairman; A. F. Dorley, H. N. Rodenbaugh.

(1) REVISION OF MANUAL.

Changes in the Manual under the heading of "Water Service" in the 1915 edition of the Manual are recommended in Appendix A.

(2) STUDY REGULATIONS OF FEDERAL OR STATE AUTHORITIES RELATING TO SUPPLY OF DRINKING WATER ON TRAINS AND PREMISES OF RAILROADS.

A progress report on this subject appears in Appendix B.

(3) DESIGN OF IMPOUNDING RESERVOIRS AND CONDITIONS UNDER WHICH THEY ARE ECONOMICAL.

This report is submitted as information only, and the Committee recommends that it be referred back for purposes of revision and enlargement with inclusion of considerable data on hand which must first be further studied before final presentation.

(4) PLANS AND SPECIFICATIONS FOR TYPICAL WATER STATION LAYOUTS.

Study of this subject was deferred.

(5) SUITABLE TYPES OF METERS FOR USE IN RAILROAD WATER SERVICE, METHODS FOLLOWED IN TESTING AND READING METERS, AND CHECKING THE CONSUMPTION OF CITY WATER.

A report on this subject appears in Appendix D and is submitted as information.

(6) LOCOMOTIVE FLUE FAILURES WHICH MAY BE DUE TO IMPROPER WATER CONDITIONS AND METHODS OF TREATMENT TO CORRECT SUCH CONDITIONS.

A report on this subject appears in Appendix E and is submitted as information.

(7) RULES AND EXAMINATION QUESTIONS FOR CARE OF PUMPING STATIONS.

A final report on this subject is submitted in Appendix F for adoption and publication in the Manual.

CONCLUSIONS.

Your Committee requests the following action on its report:

1. That the changes in subject-matter on Water Service under the heading "Revision of the Manual," be adopted and substituted for matter now given in the Manual.

2. That the report on progress of regulations with reference to purity of drinking water furnished on trains and premises of railroads be received as information.

3. That the final report on impounding reservoirs be received as information.

4. That the matter of plans and specifications for typical water station layouts be given more definite title.

5. That the report on meters be received as information.

6. That the report on locomotive flue failures and methods of correcting water conditions be received as information.

7. That the report on rules and examination questions for care of pumping stations be adopted by the Association and inserted in the Manual.

SUGGESTED SUBJECTS FOR NEXT YEAR'S STUDY AND REPORT.

1. Report on suitable methods for chemical storage at water softening plants.

2. Report on progress of regulations and methods for supplying pure water for drinking purposes on trains and premises of railroads.

3. Study of economies to be derived from impounding reservoirs.

4. Report on methods of supplying drinking water to passenger equipment with smallest possible opportunities for contamination.

Respectfully submitted,

COMMITTEE ON WATER SERVICE.

Appendix A.

(1) REVISION OF MANUAL.

J. L. Campbell, Chairman, Sub-Committee.

Pages 450 and 451.

Manual.—(As revised in 1918, shown on page 76, Bulletin 207.) Foaming of treated water is caused by the presence of sodium salts resulting from treatment to eliminate incrusting sulphates and by the presence of alkali salts and matter in suspension in the water.

Concentration of foaming salts in locomotive boilers reaches the critical point between 100 and 200 grains per gallon, depending upon the character of the foaming salts and the amount of suspended matter in the water. To prevent foaming the concentration must be kept below that point.

The grains per gallon of foaming matter in solution represent the minimum percentage of water which must be wasted from locomotive boilers to keep the concentration at the critical point.

The cost of so maintaining the concentration equals the cost of pumping, treating, and heating to the temperature of boiling water not less than 700 gallons of water for each pound of foaming matter per thousand gallons of water.

The best results are obtained by a frequent systematic blowing off of boiler while the locomotive is running and occasional complete blowing down and washing the boiler at terminals.

When unavoidable concentration of foaming salts is so great that the required amount of blowing off is impracticable or uneconomical, it is necessary to use anti-foaming compounds.

Suggested Revision:

Foaming and Priming.

"Foaming" is the term applied to the action of a boiler when the steam bubbles up over the surface of the water to such extent that the steam space and dome are filled, and syphoning action is started which causes water to be carried over with the steam into the engine cylinders. Under these conditions steam loses much of its expansion properties and the effective operation of the locomotive is thereby materially impaired.

This action is due primarily to the presence of suspended matter in the water. The suspended matter gives a mechanical strength or tenacity to the liquid in the thin films over the steam bubbles, which, rising to the surface, retain their films and collect to produce foam. It is aggravated by the concentration of alkali salts present in the natural waters or added by the process of water softening, which increases the viscosity of the surface films.

The concentration of foaming salts reaches a critical point between 100 and 200 grains per gallon, depending upon the character of the alkali salts and the amount of suspended matter in the water. To prevent

foaming the concentration must be kept below this point. The best results are obtained by the systematic and frequent blowing off of the boilers, and occasional complete blowing down and washing boilers at terminals. The cost of maintaining the concentration below the critical point equals the cost of pumping, treating, and heating to boiler temperature the amount of water necessary to be blown out.

When the unavoidable concentration of foaming salts is so great that the required amount of blowing off is impractical or uneconomical, anti-foaming compounds can be used with good results.

"Priming" is the sudden evolution of steam from a heating surface which throws water in sudden, large volumes up into steam space, and is due either to poor design of the boiler and to its being worked beyond capacity, or to the sudden opening of the throttle. While the effect upon the locomotive is temporarily the same, priming is different from foaming and can be mechanically controlled to large extent by proper handling of the engine.

Appendix B.

STUDY REGULATIONS OF FEDERAL OR STATE AUTHORITIES RELATING TO SUPLY OF DRINKING WATER ON TRAINS AND PREMISES OF RAILROADS.

R. C. BARDWELL, Chairman, Sub-Committee.

The development of more standard procedure in the supervision and progress of the regulations in regard to drinking water for use on railroad trains has been held largely in abeyance during the past year, the general form for certifying the limits of permissible contamination in previous use having been continued as a matter of routine.

The exceedingly heavy call on the country for medically trained men and experienced sanitary engineers for service with the military forces, while not exactly denuding the country, has left but the mere skeleton of the former progressive and effective force, whose time has clearly been taken by actual duties of maintaining the general health with but little or no prospects for constructive investigation along lines of lessening and removing the fundamental sources of trouble.

The laboratory cars of the Public Health Department have been used for military and Red Cross purposes and the remarkable general results in the improved physical condition and the high health rate of our Army and Navy appears to have warranted the use of all of the facilities at hand.

The meeting of Health Authorities for standardization of water inspections was postponed in the press of the more serious activities.

With the coming of peace and the return to industrial pursuit of our Army, the efforts and facilities of the Public Health Department will undoubtedly again be directed toward the promotion and improvement of conditions for the general public health, and if it is the pleasure of the Association, your Committee will be pleased to note and report any future suggestions or developments in this activity which pertains to Railroad Water Supply.

Appendix C.

DESIGN OF IMPOUNDING RESERVOIRS AND CONDITIONS UNDER WHICH THEY ARE ECONOMICAL.

E. H. Olson, Chairman, Sub-Committee.

Reservoirs used for supplying water for railroad purposes generally only require comparatively small drainage areas and obviously stream flow observation are very limited and probably in the majority of cases entirely lacking, consequently the application of some method based on other obtainable physical data is highly desirable; but this should be supplemented by at least some short term stream flow records.

Conditions of Economy.

Generally impounding water supply reservoirs are economical and justified at such points or places where the cost of the water so furnished does not exceed that of any other usable and equally dependable supply.

Impounding Reservoirs.

These are the chief source of water supply in localities where the surface streams have intermittent flow, where the water in surface streams is too bad for treatment, where the sub-surface supply is insufficient or untreatable, and where there is sufficient rainfall to produce an adequate surface run-off.

The classes of impounding reservoirs referred to in this article relate to those situated in draws or small valleys supplied by surface run-off only and having comparatively small drainage areas, and where the watershed contains no bodies of water other than the reservoir.

Location or Site.

If possible a site should be chosen for the reservoir which is higher than the point at which the water is to be delivered, thereby securing the much-desired gravity pipe line. The gravity feature of a reservoir is worth the capitalized value of pumping which can either be put in pipe line or reservoir.

In general no site should be selected which has a drainage area of less than 2.50 square miles, with a deep and steep storage basin permitting a water depth of at least 25 feet. However, local conditions may vary this. The ratio between the land area of watershed and the high water contour in proposed reservoir should be not less than 35, preferably not less than 40. The surface character of the watershed should be such that a maximum surface run-off is secured. This condition in general calls for a drainage area of rather steep slopes of impervious material and non-cultivated surface and of principally short grass vegetation, thereby reducing silt to a minimum. Matters of watershed jurisdiction, possible water pollution and water diversion should be carefully considered, as well as favorable dam and spillway sites.

The capitalized value of the cost of furnishing water should be ascertained both for present consumption and twice and three times present supply, being sure to take all cost items into consideration, the following being suggested items, viz:

Cost of present plant and equipment.
Cost of future additions.
Interest on cost.
Renewals.
Maintenance.
Operation (includes treatment).
Cost of water when purchased.
Economical benefits from improved quality.

Knowing the actual total present cost of water and having estimated the cost of double and three times the present consumption, we will then have figures serving as guides in determining the approximate limiting permissible expense that might be profitably invested in an impounding reservoir.

Approximate estimates should now be prepared and if the project is found to be feasible, more detailed study should be made of all contributary factors in somewhat the following order:

Water Requirements.

The maximum present and near future demands should be known.

The history of the increase in traffic on the particular line on which the water station is to be located should be known. If traffic history is not available, it is reasonably legitimate practice to design the reservoir for at least twice the immediate or near future demands for intermediate main line stations and at least three times for terminals.

On some main lines the terminals or division points double their water requirements about every ten years, while at intermediate points this occurs every 20 to 25 years.

No reservoir (even on branch lines) should be constructed that is not capable of supplying at least twice the present or near future demands.

Drainage Area.

The size and character of the drainage area will necessarily be largely governed by the local topography and precipitation. The surface should be of non-porous soil and steep slopes, as previously mentioned; thereby securing a high rate surface run-off. The watershed should include no closely inhabited area.

The sub-surface run-off is neglected in this discussion as far as it pertains to the furnishing of a water supply to the reservoir. Excessive drainage area should be avoided as this is conducive to lack of control or jurisdiction, thereby increasing liability to pollution; also an excessive watershed may entail a large and costly spillway.

The size of the drainage area should be carefully ascertained.

The elevation of the water table should be determined at several places, including a point near the dam site.

Reservoir or Storage Basin.

The site should be as close as possible to the point of consumption. Its shape should be such that a minimum water surface is exposed to evaporation. It would be desirable to have it surrounded with timber to break up the winds and throw a maximum amount of shade on the water surface.

The reservoir should be carefully examined as to the impervious character and dip of the strata of material that constitutes its bed and banks, having in mind the securing of as nearly as possible a water-tight storage basin. Its shape should be deep and contracted with steep banks and flat bottom, generally the minimum water depth should be three times the water evaporation plus the seepage, but in no event less than 25 feet. This gives a little leeway for silting. The following factors necessarily need modification in studying site, elevation, exposure, temperature, wind, humidity, character of precipitation, size, shape, nature of material, dip, elevation of water table and capacity.

Location.—Has reference to both the physical and geographical situation.

Elevation.—Has reference to its height above the sea and relative height of surrounding country, and also is a factor in evaporation.

Exposure.—Has reference to its protection from the elements, but principally from the prevailing winds and wave action.

Temperature.—The most important element causing water evaporation.

Wind.—This is causative of evaporation and wave action.

Humidity.—This is a factor in evaporation.

Character of Precipitation.—This refers to the manner in which the rain falls, viz: whether the prevailing rains are light or heavy.

Size.—This depends on the local topography and whether large storage is desired.

Shape.—The ability to furnish a continuous supply depends very largely on the shape, because if its banks are flat the water surface will obviously be large, requiring heavy water supply to raise the surface elevation and at the same time it will be subjected to maximum evaporation and possibly heavy seepage, these two items affecting the water level in a vertical direction regardless of the exposed surface.

Nature of Material.—The success of the project may depend entirely on this, for if porous the seepage may be excessive.

Dip.—If there is a pronounced dip it may be indicative of faults, and if of pervious material it may make sealing difficult and be causative of heavy seepage.

Water Table.—A low water table may be responsible for considerable seepage, while a high water table may prevent seepage almost entirely.

Capacity.—There should be sufficient capacity to maintain the supply throughout the longest and driest season.

Basic Data.

Stream Gaging.

One of the first things to do is to establish a relation between rainfall and surface run-off to serve as a check on the computations. Some method of gaging the discharge from the particular drainage area should be maintained during at least several successive rains. A weir may be built, a current meter used or gage boards placed at appropriate places. Sufficient data should be taken so that the amount of water discharged may be somewhat accurately known. This gaging should be in the vicinity of the proposed dam location. A rain gage should also be placed in the same vicinity so that the same party could take all readings. During rapid fluctuations it might be desirable to take readings every 15 minutes, otherwise probably every hour, while under nearly steady flow a few times in 24 hours may be sufficient. These observations could be carried on at the same time that data for a contour map was being secured for the reservoir and soundings taken at the dam and spillway sites. This work will generally take at least one month, and possibly several, during which time several rains may occur.

Data From Weather Stations.

Get the average and the annual rainfalls from the oldest weather station in the district. Examine for occurrences of two successive or single drought years and whether they were preceded by one or two or more years of average rainfall, then do likewise for several of the nearest surrounding weather stations. (See Table IV and Plate A and note close relationship between the annual rainfall at the three weather stations.) Then compare the monthly rainfalls at the same stations for the prospective period to be studied. (See Tables I, II and III.) Now select from the data collected two successive years having average rainfall and succeeded by one or two drought years and if there is reasonable agreement between the several stations get the daily rainfall records from the one nearest to the watershed and most likely to be in the path of the rainstorms reaching the drainage area for the two average years and the drought period. It is generally a good plan to go back one extra year and to include the year succeeding the drought period. (See Tables I, II and III.)

The average annual and monthly temperature and wind velocity should be secured at the same time that the rainfall records are obtained. An average annual figure for the humidity is probably sufficient, as generally it is of minor importance and whose value fluctuates but little. (See Tables V, VI and VII.)

Governing Factors.

Before using the data already collected, the following major factors should be analyzed and suitable figures ascertained which might be applicable in the case to be investigated, viz.:

Precipitation.
Land Evaporation.
Transpiration.
Interception.
Run-off { Surface flow / Sub-surface flow.
Water Evaporation from Reservoir.
Seepage from Reservoir.

Precipitation.

The two principal sources of moisture are rain and snow, their relative importance depending on geographic locality. The water equivalent of snow is determined by the conventional ratio of ten volumes of snow to one volume of water.

There should be a sufficient amount of rain or snow and the intensity and frequency should be such as to produce a considerable surface run-off.

For the class of watershed under discussion a rain or snowstorm usually covers the entire area.

In an investigation of this kind we are principally concerned with years having normal and less than normal rainfall, excepting for purposes in determining the size of the spillway when the maximum precipitation governs.

The following list indicates where some long-time weather records are available:

New Bedford, Massachusetts	102 years
Boston, Massachusetts	98 years
Providence, Rhode Island	84 years
Marietta, Ohio	94 years
Portsmouth, Ohio	83 years
Cincinnati, Ohio	81 years
Washington, District of Columbia	64 years
Savannah, Georgia	64 years
New Orleans, Louisiana	68 years
St. Louis, Missouri	79 years
St. Paul, Minnesota	79 years
Havre, Montana	36 years
Salt Lake City, Utah	41 years
El Paso, Texas	37 years
San Diego, California	66 years
San Francisco, California	66 years
Astoria, Oregon	62 years

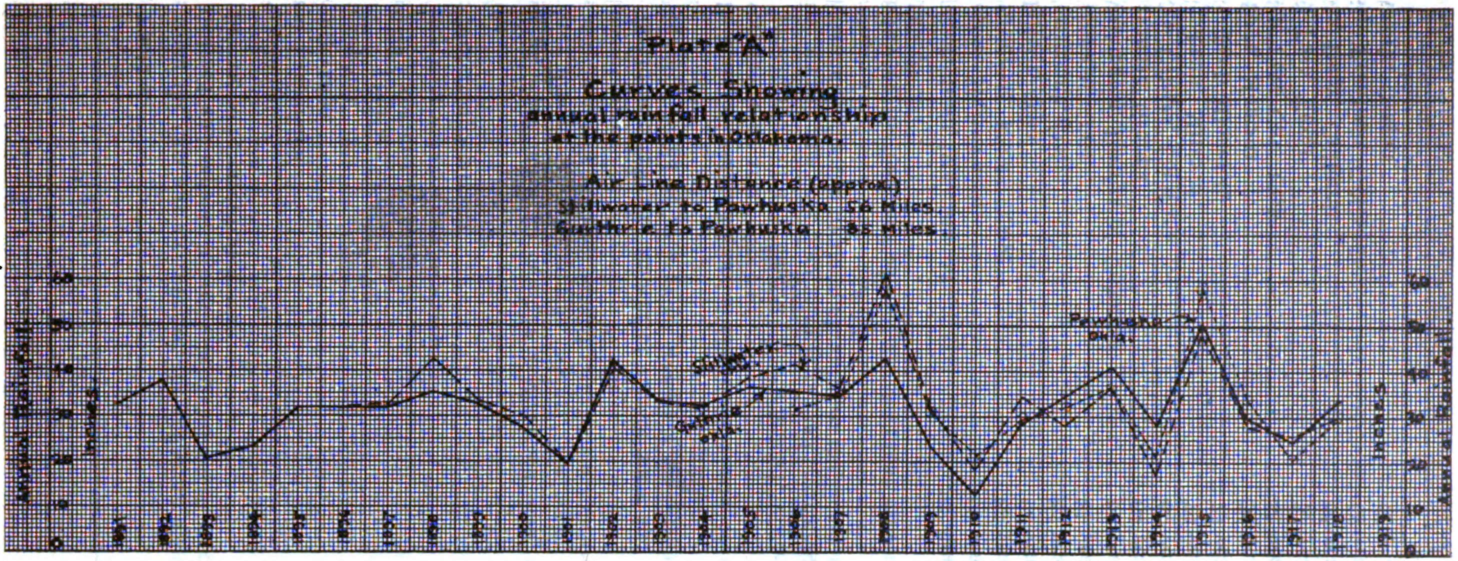
Plate "A"
Curves Showing
annual rainfall relationship
at the points in Oklahoma.
Air Line Distance (approx)
Stillwater to Pawhuska 56 Miles.
Guthrie to Pawhuska 85 Miles.
Annual Rainfall.
Inches
Stillwater Okla.
Guthrie Okla.
Pawhuska Okla.

TABLE I.—DAILY AND MONTHLY RAINFALL AT PAWHUSKA, OKLAHOMA, FOR YEAR 1916.

(In Inches.)

Days.	Jan.	Feb.	Mar.	April.	May.	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1					T							
2				.65	.20			.80	.61			
3												
4				T								
5						1.40						
6						.54						
7												
8								.60	.82		1.44	
9												
10						.55						
11					T					.11		
12	1.32					.70			.85	.17		
13				T		1.01						
14				.25	.30	.98				.46		T
15				.45		.23				1.55		
16								.40				
17						.74			T			
18						.63						T
19										.30		
20	.35			.25	.35		.18					
21	1.50								.23		.43	.30
22											.66	
23												
24						.80			.10	.10		
25			3.50	.03		T						
26	1.20		.63			.42		.42			.50	.51
27		T						.60				
28	.10				1.30							
29												
30				.50								
31			.19					.82				.10
Total for Month	4.47	T	4.32	2.13	2.15	8.00	.18	3.64	2.61	2.69	3.03	0.91

T = Trace. Total for year, 34.13 inches.

TABLE II.—DAILY AND MONTHLY RAINFALL AT STILLWATER, OKLAHOMA, FOR YEAR 1916.

(In Inches.)

Days.	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	.02			.65	.60			.12	.13			
2				.32	.04							
3				T	.03				.15			
4					T							
5				.10		.21						
6						.90						
7				.65		.06						
8		T		.06				T	.22		.33	
9						.02		.11			.87	
10	.02					.38						
11	T	.01				.03						
12	.40					1.24			1.03	T		
13						T				.05	T	
14				.76	.03	2.85					T	.10
15				1.09	.06	.02				1.75		.05
16										.02		
17								T	T			
18					.05							.02
19									.06			
20	T			T			.18			.03		
21	1.15			.03	.11	.01			.01		T	.20
22		.02							T		1.46	.10
23												
24			.06			.89						
25			.96			1.33			.21	.26		
26	.25		.03	.11		.01						.31
27	1.14		.63		.02	1.54		.32	T			
28	.05	.26						.17			.23	
29	T									T		
30	.15											
31			.02					.15				.15
Total for Month	3.18	0.29	1.70	3.77	0.94	9.49	0.18	0.72	1.81	2.11	2.89	0.93

T = Trace. Total for year, 28.01 inches.

TABLE III.—DAILY AND MONTHLY RAINFALL AT GUTHRIE, OKLAHOMA, FOR YEAR 1916.

(In Inches.)

Days.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	......	......	......	.70	.05	......	......	......	......	......	......	......
2	......	......	......	.40	.06	......	......	......	.10	......	......	......
3	......	......	......	......	......	......	......	......	.15	......	......	......
4	......	......	......	......	......	......	......	......	......	......	......	......
5	......	T	......	.08	......	1.30	......	......	......	......	......	......
6	T	......	......	.15	......	.12	......	......	......	......	......	......
7	......	......	......	.55	......	......	......	......	T	......	......	......
8	......	......	......	......	......	......	......	T	......	......	1.50	......
9	......	......	......	......	......	......	......	......	......	......	......	......
10	......	......	......	......	......	.08	......	......	......	......	......	......
11	......	......	......	......	......	......	......	......	......	......	......	......
12	.30	......	......	......	......	......	......	......	1.30	.30	......	......
13	......	......	......	......	......	......	......	......	......	......	T	......
14	......	......	......	.80	.05	1.75	......	......	......	.30	......	.40
15	......	......	......	.20	......	......	......	......	......	1.05	......	......
16	......	......	......	......	......	......	......	......	......	.15	......	......
17	......	......	......	......	......	......	......	......	......	......	......	......
18	......	......	......	......	......	......	......	......	......	......	......	......
19	......	......	......	......	......	......	......	......	......	......	......	......
20	.60	......	......	T	T	......	.80	......	......	......	......	......
21	.80	......	......	......	......	......	......	......	......	......	1.05	.40
22	......	.03	......	......	......	......	......	......	......	......	.65	......
23	......	......	......	......	......	.45	......	......	......	......	......	......
24	......	......	......	......	......	1.10	......	......	......	.30	......	......
25	......	......	......	.30	......	2.50	......	......	......	......	......	......
26	2.50	......	......	.08	......	.30	......	......	......	......	......	1.25
27	......	......	......	......	T	......	......	.05	......	......	......	......
28	.05	.05	......	......	......	......	......	......	......	......	......	......
29	......	......	......	......	......	......	......	......	......	......	......	......
30	.10	......	......	.80	......	......	......	......	......	......	......	.18
31	......	......	......	......	......	......	......	.15	......	......	......	......
Total for Month	4.35	0.08	0.00	4.06	0.16	7.60	0.80	0.20	1.55	2.10	3.20	2.23

T = Trace. Total for year, 30.05 inches.

TABLE IV.—ANNUAL RAINFALL IN OKLAHOMA AT

Year	Guthrie	Stillwater	Pawhuska
1891	32.27	.....	.....
1892	37.94	.....	.....
1893	20.15	.....	.....
1894	22.99	28.46	.....
1895	30.71	31.05	.....
1896	31.71	31.40	.....
1897	31.76	31.69	.....
1898	35.15	42.62	.....
1899	32.62	32.87	.....
1900	27.33	29.98	.....
1901	19.71	19.98	.....
1902	42.19	40.29	.....
1903	33.42	32.58	.....
1904	32.19	31.35	.....
1905	36.30	38.59	.....
1906	35.13	41.50	31.13
1907	34.22	36.65	34.33
1908	42.65	61.10	57.69
1909	23.61	31.76	30.96
1910	12.41	18.22	21.75
1911	28.12	34.43	29.73
1912	34.67	27.60	32.20
1913	40.88	36.59	36.19
1914	27.93	16.79	20.89
1915	50.10	48.02	58.18
1916	30.05	28.01	34.13
1917	24.45	24.59	30.37
1918	33.52	29.90	29.02

TABLE V.—MONTHLY TEMPERATURE FOR YEAR 1916 AT GUTHRIE, STILLWATER, PAWHUSKA AND LAWTON, OKLAHOMA.

STATIONS	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
Guthrie..........	35.5	4.05	0.00	57.4	72.9	76.5	83 5	84.7	74.2	64.1	50.8	38.7	56.6
Stillwater.........	31.3	36.2	51.9	53.5	49.2	74.1	81.2	81.0	70.7	61.3	49.9	36.1	56.4
Pawhuska.........	33.9	38.0	54.0	56.8	70.3	74.2	82.7	83.6	73.7	62.4	50.3	37.0	59.7
Lawton—Temperature............	62.8	53.5	44.2	35.4	42.8	54.8	55.4	69.6	77.4	81.3	83.5	78.4	61.6
Lawton—Evaporation............	7.66	5.34	1.99	.79	.85	1.88	2.64	9.48	11.83	10.34	11.17	7.20	5.93

TABLE VI.—MONTHLY WIND VELOCITY FOR YEAR 1916 AT OKLAHOMA CITY.

STATION	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
Oklahoma City....	16.9	13.8	18.3	17.0	16.8	13.8	7.9	11.9	12.8	11.5	16.2	14.2	14.3

TABLE VII.—MONTHLY HUMIDITY FOR YEAR 1916 AT OKLAHOMA CITY IN PER CENT.

STATION	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
Oklahoma City....	84	76	54	74	67	73	65	60	67	68	70	67	68.7

Land Evaporation.

The evaporation from land areas usually is the most important factor in determining run-off from a watershed. It varies with the rainfall, season, temperature, slope, humidity, vegetal cover, wind, topography, surface and subsoils. Of these, temperature is the most important factor governing the rate of evaporation, as the rate of evaporation from land varies closely with the temperature.

Frequent light rains keeps the surface soil and vegetation moist, thus favoring greatest evaporation, while slow, steady rains favor ground percolation. Torrential rains favor surface run-off. All forms of vegetation reduce the rate of evaporation of free moisture, particularly due to the shading produced. The annual land evaporation loss varies from about one-quarter to two-thirds of the yearly rainfall. (See Plate B for typical land evaporation curve.)

*C. S. Slichter (in Eng. News, July 5, 1906) reports that from a water surface in Kansas from August 6 to September 3, 1905, the water evaporation was 10.90 inches, while the evaporation from cultivated soil with the water table one foot below the surface was 4.88 inches and from uncultivated soil with water table at the same level it was 5.83 inches. The soil evaporation for a capillary lift of two feet was 2.23 inches and for three feet 0.80 inches.

From Bulletin 248, Office of Experiment Stations, U. S. Dept. of Agriculture, 1912, the ratio of soil to water evaporation varies from 2 to 7 tenths and for clay loam it was 3 tenths, the air temperature varying from 64 to 79 deg. F., see Plate "B."

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Transpiration.

This is a process of vaporization of water from the breathing pores of leaves and other vegetable surfaces. Transpiration is practically limited to daylight hours and to the growing season. The amount of water used by plants during the growing season depends mainly on the quantity available within reach of the root system.

The moisture in the soil may for practical purposes be divided into two portions, namely, "gravity water" and "capillary water." The former is that portion which will be drawn down into the lower layers of the soil by gravity (some of which may reappear elsewhere as seepage water) and the latter is that portion which is held in place in the soil by capillary attraction, generally at an elevation of several feet above the water table. Of the capillary water nearly one-half is available for plant growth and the remainder will readily evaporate.

In estimating the transpiration loss from a watershed the exact character of the vegetation is not as important a factor as it might first appear except for lands in arid and semi-arid regions. Nearly all watersheds have mixed vegetation and consequently does not vary between considerable limits.

For tentative purposes 6 to 10 inches may be used for entire area for the season. The values of monthly distribution of the total seasonal transpiration is determined mainly by the monthly mean air temperature. These monthly values may have to be modified for deficient or excessive precipitation and ground water supply in the soil occupied by the root system to ascertain the probable monthly transpiration, under the given conditions. Slope has no marked effect on transpiration.

See Plate "B" for typical transpiration curve.

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Interception.

During the summer a considerable portion of the rainfall is intercepted by trees, shrubs and other vegetation and re-evaporated without ever reaching the ground, hence interception is at a maximum when the vegetation is most luxurious.

In winter evergreen trees intercept large quantities of snow. According to observations, the annual amount intercepted varies from 15 to 40 per cent. of the yearly rainfall. It is approximately constant for each shower.

This loss is generally included in the land evaporation loss.

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Percolation.

Percolation is favored by slow and steady rains, pervious soil and flat slopes. All forms of vegetation reduce percolation by absorbing a large amount of the capillary water, which would otherwise be held over from one rain to the next, and would permit most of the rainfall, absorbed by the surface soil, to percolate down to the water table instead of first replenishing the water used by the plants. The rate of percolation is largely affected by the initial condition of the soil, that is, whether moist or dry and if tilled.

For low capillary lifts, sandy soil will supply much more water at the surface of the ground for evaporation and transpiration than clay soils. On the other hand, clayey soils will supply moisture at the surface, even when the water table has dropped far out of reach in sandy soils. Hence the depth of the water table is an important factor in determining the evaporation opportunity.

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Run-Off.

This is the name applied to that part of the precipitation which is carried off (from the land upon which it fell), ultimately to the ocean largely through surface channels.

It is in reality the residual precipitation after interception, land evaporation, transpiration and seepage losses have been deducted. In round numbers, 15 to 25 inches generally represents the annual losses, due to interception, land evaporation, transpiration and seepage. Generally anything less than ½-inch rainfall will produce no run-off. Broadly speaking, run-off consists of surface and sub-surface flow. (See Tables VIII to XIV.)

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TABLE VIII.—MONTHLY RAINFALL AND RUN-OFF IN INCHES AT LECOMPTON, KANSAS, FOR YEAR 1904.

KANSAS RIVER.

Drainage Area, 58,550 Square Miles.

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Rainfall...........	0.77	0.22	3.96	4.70	7.85	5.42	9.90	4.77	2.12	0.64	0.23	0.56	41.14
Run-off............	0.09	0.07	0.11	0.25	0.32	0.48	0.71	0.12	0.09	0.12	0.07	0.06	2.48

TABLE IX.—RAINFALL AND RUN-OFF IN INCHES OF SUDBURY RIVER NEAR FRAMINGHAM, MASS., YEARS 1876 TO 1916.

Drainage Area, 75.2 Square Miles.

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Rainfall...........	4.10	4.17	4.32	3.54	3.27	2.94	3.69	3.86	3.29	3.84	3.76	3.84	44.62
Run-off............	2.169	2.803	4.884	3.411	1.893	.820	.322	.428	.374	0.751	1.294	1.738	21.69

TABLE X.—RAINFALL AND RUN-OFF IN INCHES OF LAKE COCHITUATE NEAR COCHITUATE, MASS., YEARS 1864 TO 1916.

Drainage Area, 17.6 Square Miles.

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Rainfall...........	3.88	3.94	4.30	3.48	3.57	3.01	3.77	4.09	3.51	4.07	3.94	3.61	45.17
Run-off............	1.98	2.53	3.83	2.88	1.72	.79	.47	.68	.67	0.94	1.29	1.62	19.40

TABLE XI.—RAINFALL AND RUN-OFF IN INCHES OF ROCK RIVER NEAR ROCKTON, ILL., FOR YEARS 1903 TO 1908.

Drainage Area, 6,290 Square Miles.

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Rainfall...........	1.80	1.32	2.75	2.80	4.42	3.69	3.64	4.48	3.62	2.12	1.55	1.70	34.89
Run-off............	1.00	.83	2.11	1.46	1.06	.82	.61	.43	.43	.49	.42	.44	10.10

TABLE XII.—RAINFALL AND RUN-OFF IN INCHES OF ROOT RIVER NEAR HOUSTON, MINN., FOR YEARS 1909 TO 1911.

Drainage Area, —

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Rainfall...........	1.04	.70	1.22	1.75	4.75	2.40	3.22	4.82	3.60	2.78	2.38	1.34	30.00
Run-off............	.28	.30	1.13	.56	.46	.34	.36	.48	.32	.44	.40	.36	5.43

TABLE XIII.—AVERAGE ANNUAL RUN-OFF FROM TWELVE EASTERN WATERSHEDS.

Name.	Drainage Area Sq. Miles.	Length of Time, Years.	Rainfall, Inches.	Run-Off, Inches.	Other Losses, Inches.
Muskingum River	5,828	8	39.7	23.1	26.6
Genesee River	1,070	9	40.3	14.2	26.1
Crafton River	339	23	49.4	22.8	26.6
Lake Cochituate	18.9	38	47.1	20.3	26.8
Sudbury River	78.2	26	46.1	22.6	23.5
Mystic Lake	26.9	18	44.1	20.0	24.1
Neshaminy Creek	139.3	16	47.6	23.1	24.5
Perkiomen Creek	152	16	48.0	23.6	24.4
Tohickon Creek	102.2	.15	50.1	28.4	21.7
Hudson River	4,500	14	44.2	23.3	20.9
Pequannock River	63.7	9	46.8	26.6	20.0
Connecticut River ..	10,234	11	43.0	22.0	21.0

TABLE XIV—ANNUAL RUN-OFF FROM LAKE COCHITUATE FOR 38 YEARS.

Year.	Rainfall.	Run-Off.	Other Losses.	Year.	Rainfall.	Run-Off.	Other Losses.
1863.......	67.69	26.71	40.98	1882.......	41.95	15.53	26.42
1864.......	43.37	19.19	24.18	1883.......	30.23	10.09	20.14
1865.......	50.43	20.70	29.73	1884.......	43.40	18.33	25.07
1866.......	61.31	15.58	45.73	1885.......	46.65	15.75	30.90
1867.......	58.67	22.44	36.43	1886.......	43.52	21.46	22.06
1868.......	51.16	24.93	26.23	1887.......	43.55	24.61	18.94
1869.......	58.81	19.19	38.82	1888.......	55.07	26.47	28.60
1870.......	58.68	28.48	30.20	1889.......	53.19	30.15	23.04
1871.......	45.34	14.72	30.62	1890.......	48.67	25.66	23.01
1872.......	48.29	17.22	31.07	1891.......	48.51	32.58	15.93
1873.......	44.90	25.66	19.24	1892.......	41.03	16.11	24.92
1874.......	38.18	21.69	16.49	1893.......	41.43	16.81	24.62
1875.......	46.25	16.86	29.39	1894.......	39.73	13.53	25.20
1876.......	46.30	19.77	26.53	1895.......	50.63	18.91	31.72
1877.......	45.91	22.20	23.71	1896.......	43.34	21.21	22.13
1878.......	49.48	24.24	25.24	1897.......	42.13	16.20	25.93
1879.......	39.53	20.81	18.72	1898.......	56.08	22.86	33.22
1880.......	36.87	10.73	26.14	1899.......	40.48	20.24	20.24
1881.......	39.82	15.55	24.27	1900.......	50.56	18.30	32.26
				Mean......	47.13	20.32	26.81

Table XIV illustrates the variation between run-off and rainfall.

Surface Flow.

Heavy rates of precipitation cause large surface flow. The varying quantities of surface run-off from different watersheds are principally due to the different amounts of moisture necessary to saturate the ground, interception and the perviousness of the drainage area. (See Table XIV.)

Substantially all of the rain falling upon frozen, ice-covered ground will run off into the water course and when carrying ice and snow with it in sufficient quantities the surface flow may exceed the rainfall.

In spring and fall when the land evaporation and transpiration losses are small all soils, as a rule, carry substantially the entire possible amount of capillary water, between rains. Under such conditions the capacity of sand for gravity water is about four inches per vertical foot, while the capacity of heavy clay is but a little more than one inch per vertical foot. In consequence of which clay soils quickly become saturated and thereby permit large surface flow.

Tilled land will facilitate ground absorption of the rainfall, thus reducing the surface flow.

Surface flow resulting from moderate rains is retarded and to some extent diminished by lakes, ponds or holes no matter how small they are.

On the Mississippi River watershed (except possibly near the Gulf of Mexico) and throughout the greater part of the United States, the normal rainfall is insufficient to supply the needs of transpiration and land evaporation at the prevailing temperatures; consequently, a large portion of any increased rainfall goes to supply unsatisfied needs of transpiration and land evaporation and hence a comparatively small portion of the increased rainfall, within certain limits, appears as run-off.

Sub-surface or Seepage Flow.

The water contributed to streams as seepage flow consists of ground water supplied by percolation. Not all the percolating water, however, reaches the streams; portions are lost through evaporation, transpiration and a small varying amount to deep seepage. When the capillary water has become wholly or partly depleted through evaporation and transpiration, percolation must first replenish the capillary water before the soil will permit gravity to draw water down into the ground water reservoir which supplies the seepage flow of streams.

Capillary water amounts to about half an inch in sand to three inches in heavy clay per foot in depth.

Clay soils retard percolation and facilitates surface run-off.

Effect of Character of Precipitation.

When the rainfall is insufficient to keep the ground continually moist, which is usually the case, the character and rate of rainfall are the factors which most largely influence seepage flow. When there is no frost in the ground, or the ground was relatively dry when it froze, slowly melting snow permits of the greatest percolation. On the whole, a greater

proportion of snowfall than rainfall eventually percolates into the ground to supply seepage flow.

Next to snowfall in effectiveness in replenishing the ground water supply are the slow, drizzling rains that occur over large portions of the country during spring and fall, when both evaporation and transpiration demands are relatively small.

The increase in seepage flow which will result from a given increase in the ground water supply, through percolation, will depend upon the slope of the ground water surface and the resistance of the subsoil to the flow of water. Fine grained subsoil will maintain a steeper water table than coarse grained material, due to the difference in resistance to flow.

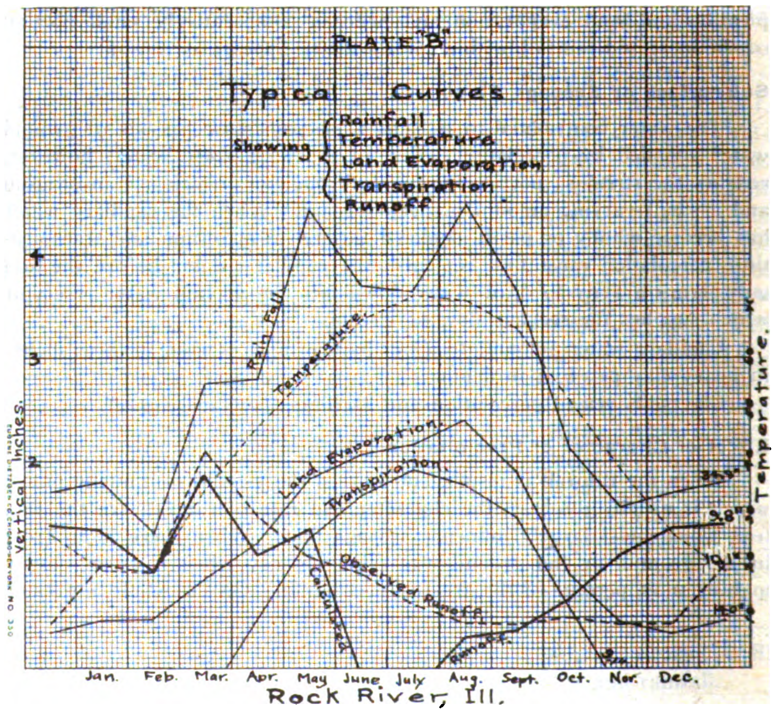
ROOT RIVER WATERSHED.

		1912		1911		Average		
Rainfall		28.6		37.5		33.1		
Transpiration		99.5	28.5	9.2	29.6	9.4	29.1	32%
Evaporation		13.0		15.1		14.0		**48%**
Surface Run-Off	6.0	2.2	5.3	3.1	5.7	2.7		20%
Sub-surface Flow		3.8		2.2		3.0		

From the preceding figures

Transpiration is	32 per cent. of rainfall.
Land Evaporation,	48 per cent. of rainfall.
Run-off,	20 per cent. of rainfall.

In this instance the run-off is about equally divided between surface flow and sub-surface flow.



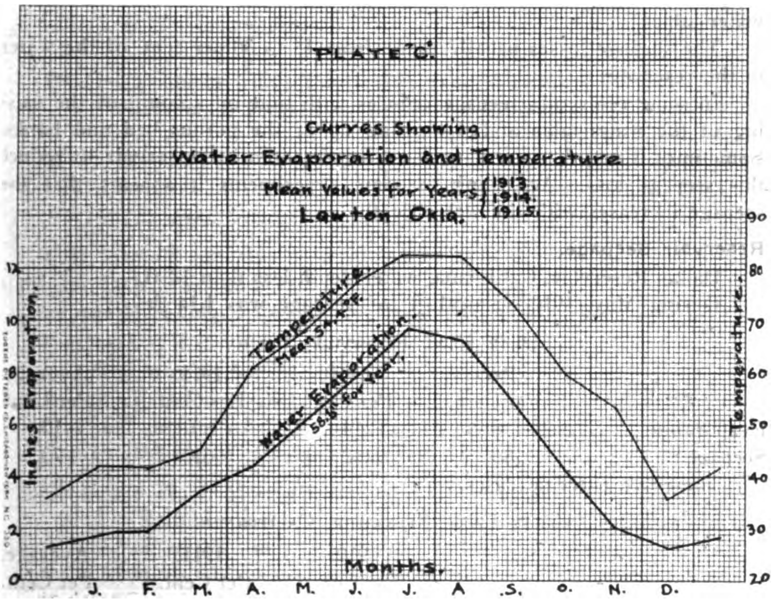
Water Evaporation.

Evaporation is the process by which water is changed from the liquid to the gaseous state.

The rate of evaporation is influenced by the temperature of the water, temperature of the air, wind, humidity and barometric pressure.

The rate of evaporation varies principally with the temperature of the air and the water. In general the mean annual water temperature is slightly higher than that of the air. The temperature of relatively shallow bodies of water follows that of the air quite closely. The extent to which the temperature of deeper bodies or lakes varies with that of the air depends primarily upon their depth. Below depths of 15 or 20 feet. the temperatures are more uniform.

The effect of wind is to lower the relative humidity over and close to the water surface; however, primarily it causes the removal of the vapor which forms more readily over the water surface than it can diffuse through the atmosphere above; the air next to the water surface being nearly saturated vapor.



The relative humidity as determined some distance from the water surface has generally but a slight influence on evaporation.

Barometric pressure is not an important factor in evaporation. Investigations show that evaporation varies inversely with the barometric pressure. (See Plate C.)

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Seepage in Reservoir.

This is dependent upon the character and the dip of the strata of material that constitute its bed and banks and on the elevation of the water-table. In regions where the water-table slopes towards the reservoir and is close to the surface, some of the percolating water flows into the reservoir as seepage when the water surface is lowered. In other regions where the water-table is at a considerable depth, as is generally the case in arid and semi-arid localities, the ground seepage losses from the reservoir might become a very important item. In such cases the character of the bed and banks is far more important than the elevation of the water-table.

The seepage losses usually range from 15 to 30 per cent. of the water in the reservoir.

In some reservoirs seepage reduces with time on account of the raising of the water-table and the silting up of the porous bed and banks. Sometimes it may be necessary to sluice clay into the reservoir to reduce this seepage loss. According to some experiments it appears that the seepage increases with the water depth.

Reservoir Seepage.

Dallas Reservoir, California, water depth less than 12 ft.

During May, 1910, vertical ft. of seepage was 1.14 ft.

DEAR FLAT RESERVOIR, IDAHO.

	1909. Per Cent.	1910. Per Cent.	1911. Per Cent.	Average. Per Cent.
Evaporation	6	14	9	10
Seepage	86	62	61	70

These are extreme cases.

CLEAR LAKE RESERVOIR, CALIFORNIA.

	1910. Per Cent.	1911. Per Cent.	Average. Per Cent.
Evaporation	57	39	48
Seepage	34	11	22½

COLD SPRINGS RESERVOIR, OREGON.

	1908. Per Cent.	1909. Per Cent.	1910. Per Cent.	1911. Per Cent.	Average. Per Cent.
Evaporation	12	10	9	9	10
Seepage	22	9	17	15	16

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CONCLUSION.

Better results will be obtained if the various factors entering into this subject are studied separately; more accurate judgment can then be made of the variable individual factors than when these variable factors are grouped.

Run-Off.

In general this is the most sought factor; most methods used for determining the same can be classed into three general groups, viz.:

I. The formula group.
II. The percentage of rainfall group.
III. Rainfall minus losses group.

Of Group I, Joel D. Justin's formula for run-off is a good example.

$$C = 0.934 S^{0.155} \frac{R^2}{T}$$

When C = annual run-off in inches from watershed.
R = annual rainfall in inches on watershed.
S = slopes of watershed { Elevation of highest minus elevation of lowest point divided by square root of drainage area.
T = mean annual temperature.

This formula can also be written as $C = K R^2$; when "K" is a constant for each drainage area.

George W. Cooley's formula for watershed without lakes:

F = 0.844 L R C.
F = flow in cubic feet per second.
R = precipitation in feet.
L = land surface of drainage area in square miles.
C = co-efficient of available rainfall.

Of Group II, F. Merritt's method is illustrative:

Rainfall.	Per Cent. Run-Off
0.5 in. to 0.5 in.	None
0.5 in. to 0.65 in.	2 per cent.
0.65 in. to 0.80 in.	5 per cent.
0.80 in. to 1.00 in.	10 per cent.
1.00 in. to 1.50 in.	15 per cent.
1.50 in. to 2.00 in.	18 in.
2.00 in. to 2.50 in.	22 per cent.
2.50 in. to 3.50 in.	30 per cent.

Group III. In C. C. Vermeule's formula, the various factors entering into rainfall losses are recognized.

$$F = R\text{-}E.$$
$$F = \text{Run-off}.$$
$$R = \text{Rainfall}.$$

E = Evaporation, which includes transpiration and other losses, and his general formula for "E" he suggests

$$E = (15.50 + 0.16R)\ (0.05\ T - 1.48).$$

Rainfall-loss method is:

Run-off = rainfall minus all losses, all losses being included in the evaporation and transpiration.

This method has been used in England and is also highly spoken of by some authorities in this country.

Determining annual run-off by various methods applied to Tohickon Creek, Pa., we get

23.5 Inches by Formula method $C = KR^2$ $K = 0.0115$.
25.2 Inches by Rainfall-loss method.
26.1 Inches by Observation.

Hence when the factors entering into this topic and their relationship is understood, the solution is not entirely one depending on method, but a clear conception and judgment in the application of the method used.

The rainfall-loss method is the most scientific and has wide elasticity in its application to the varying conditions met in practice.

Appendix D.

SUITABLE TYPES OF WATER METERS FOR USE IN RAILWAY WATER SERVICE, METHODS FOLLOWED IN TESTING AND READING METERS, AND CHECKING THE CONSUMPTION OF CITY WATER.

C. R. Knowles, Chairman, Sub-Committee.

Introduction.

When any article is purchased by weight, or measure, the quantity delivered should be checked to determine whether full value has been received. This is true of water as well as any other commodity, and the water meter is the medium through which the quantity of water delivered is measured and payment is made upon the meter registration.

Unfortunately we have fallen into, or inherited, the habit of looking upon water as a thing of little value. As a result the importance of checking meter readings is not always realized and the figures submitted by the City meter reader often accepted without question as to their accuracy, neither do we know the condition of the meter in all cases.

It is safe to say that no other commodity is purchased with as little regard for the medium through which the quantity is determined as water. Yet it is of as much importance to know that the water meter is registering accurately as it is to know that any other measuring device is correct.

Frequently the checking of meter reading is left to the Agent, or other employe, who may, or may not know, how to read the meter and is perhaps dependent on the meter reader to tell him what the reading is. It is true that the error in registration of water meters is more often in the consumers' favor than otherwise, but in the majority of cases the City water works manager has made due allowance for this percentage of error and has based rates accordingly. Therefore, it is just as essential to keep a check upon the water meter readings as it is on the gas or electric meter, or the scales weighing the coal purchased.

General.

There have been many proposed devices for measuring water, and about everything has been tried that the imagination of man can conceive.

Some devices measure water by volume, that is to say, a chamber of a given size is filled and emptied continually, and the number of times it is filled and emptied.

A second class of meters is that known as "current" meters. These meters measure water by recording the velocity of the fluid as it flows through a passage of a definite size, this velocity indicated by a recording device.

A third class of meters is that known as "proportional" meters. These meters measure a definite portion of the main stream by passing it through

a measuring device, and by thus measuring a percentage of the total flow, the whole is known and recorded on the counter.

Each of these various classes of meters has advantages peculiar to itself, and no one class will meet the requirements of all kinds of service; therefore, they are each used largely for those conditions of service for which they are found to be the best adapted.

The displacement type of meters may be divided into several classes. In one class the displacing member is a reciprocating piston, while in another the piston has a continuous or rotary motion; in another the piston has a motion of oscillation, and in another class the displacing member is a disc and has a motion called one of nutation.

Historical.

The first attempt of metering water may be credited to Sextus Julius Frontinus, who was water commissioner of the City of Rome, A. D. 97, who (according to Clemens Herschel "Frontinus and the Water Supply of Rome") measured the water furnished the citizens of Rome by means of a circular ajutage about nine inches long and of a designated diameter, each ajutage being approved and stamped by the public authority. It appears that the Romans did not develop the water meter beyond a piece of pipe with a fixed opening, and upon the decay and fall of their empire the method of measuring water was forgotten. Many devices for measuring water were used from time to time, but it was not until the early sixties that the water meter was in general use in this country.

The earlier part of the Nineteenth Century marks the beginning of water works construction on an extensive scale, and while a number of patents were issued covering various types of fluid meters, it is evident from the specifications submitted to the Patent Office that the patentees had intended their machines for measurement of fluids other than water, and that the earlier efforts to perfect devices for the measurement of water occurred about 1850.

The meters of this period, however, were not popular, as they were neither reliable or efficient, their construction being such that they caused considerable loss of head which was a serious matter especially on the low pressure lines which prevailed at that time. The stoppage of meters were frequent and invariably stoppage also meant breakage. Public opinion also was against the meter, as the public was generally satisfied with the sale of water on a flat rate basis. Thus, through opposition to meters and their general inefficiency they made but little progress for the first 15 or 20 years.

The earlier meters were small in size, and they were not used generally on railroads until within the past 15 or 20 years; even at the present time there are many "flat rates" in effect on railroads, but the flat rate is rapidly becoming a thing of the past and within a short time all water purchased will be metered, as it is obvious that the only fair basis upon which water may be purchased or sold is by meter. The water meter

has become a very essential feature in railway water supply, as considerable portion of all the water used is purchased through water meters and it is important that the type of meter and its operation be given careful consideration.

The first patent of record on a water meter was issued to W. Sewell, Jr., Williamsburg, N. Y., February 5, 1850, on what would now be considered a very crude meter of the Current Type.

Duplex Piston Meters.

The first meter of the duplex piston type was invented by J. Ericsson, of New York City, January 1, 1851, in connection with which he claimed as novel the "connecting of two pistons with two cranks of a crank shaft, so that at the end of each stroke of either of the pistons, it will remain at rest, while the crank shaft is being impelled by the other piston, so that the valves may be shifted whilst the piston is at rest." This type of meter was very much improved and simplified by Henry R. Worthington, to whom a patent was granted July 24, 1855, and from a commercial standpoint, the Worthington Duplex Piston meter may be said to be the first meter used successfully in this country, and it enjoyed popularity until the advent of the lighter and less expensive machines of the rotary and disc piston types.

Proportional Meters.

The fundamental principle relating to the operation of this type of meter was covered by letters patent to Frank G. Johnson, Brooklyn, N. Y., November 3, 1863, who stated in his application that: "The invention consists in measuring the water passing through a larger pipe by passing a relatively proportionate amount through a small tube, the water in the latter passing through, and that in the former, around the meter." Many patents have been issued covering constructive details in this type of meter, and it has claimed assiduous attention of the most prominent meter engineers, but they have thus far not succeeded in designing an efficient meter except where the measured quantity constitutes a relatively large proportion of the entire flow to be measured.

Current Meters.

This is undoubtedly the earliest type of meter, and with the many changes and improvements which have been made since the "Sewell" patent in 1850, this type has gained favor immensely, and is now the most popular type and the most universally used in the larger sizes, where service conditions are severe, and such in respect to the volume discharged, and where it is not essential to record very small flows. The efficiency of this type of meter, in recent years, has been very greatly increased by the balancing of the piston, to prevent end thrust, and since these changes have been made largely since 1890, it may be of interest to know that importance was attached to this feature many years ago, as evidenced in the claims made by Albion M. Rouse, of St. Louis, Mo., to whom a patent was granted July 8, 1873. The principal claim under such patent follows: "A

right-hand and left-hand propeller are arranged on the same shaft." "In the induction opening is a fixed deflector to throw equal quantities of water to each propeller."

Double Rotary Piston Meters.

This was the earliest form of rotary piston meters, best exemplified by the "Union Rotary," and its introduction as a popular machine followed that of the Worthington Duplex. The measuring element consisted of two segmental pistons, geared to intermesh with each other, which, by their contact with the measuring chamber and each other, divided the measuring chamber into compartments, which were successfully filled and emptied. While the "Union Rotary" was manufactured under a patent issued to Benaiah Fitts, June 13, 1876, the fundamental idea was covered by a patent, issued to Walter Payton, Sewardstone Road, Victoria Park, England, January 7, 1868.

Single Rotary Piston Meters.

The next important step in meter development gave us the single piston rotary meter, the best examples of which are the "Crown" meter, patented by Lewis H. Nash, January 21, 1879, and the "Hersey Rotary," although the radial piston lobes in this meter oscillate continuously within their separate and respective measuring compartments. In fact, the inventor, James A. Tilden, states in his specifications that "The meter can hardly be called a 'Rotary' meter because the piston does not rotate," while the so-called "Hersey Rotary" is, therefore, not a "Rotary" meter in a technical sense, its similarity in form and appearance has been responsible for such classification, commercially.

As compared with previous types, the rotary meters were equally, if not more efficient, more compact, much more easily handled and repaired, less expensive, and cost less to maintain, on account of which they displaced the "Duplex Piston" and "Double Rotary Piston" meters to a very great extent, commercially.

Oscillating Piston Meters.

While a number of patents were granted years prior on so-called oscillating pistons, with auxiliary valves and more or less complicated mechanism, the oscillating piston meter, in which the piston acts as its own valve (best exemplified by the "Empire" and the "Victor"), was originally patented by Lewis H. Nash, June 17, 1884. The piston in this type of meter functions precisely the same as in the "rotary type," it accomplishes measurement by displacement; the piston being actuated by the water which it measures, acts as its own valve in controlling the flow of water to and from the measuring compartments, or spaces.

Disc Piston Meters.

There has been much controversy concerning the credit for the invention of this, at present, most popular and most universally used type of water meter, especially for small services. As far as our own patent

office records are concerned, both as to priority or application and issuance, the credit belongs jointly to John Thomson and Frank Lambert —the latter's interest assigned to Mr. Thomas—who filed their application July 16, 1887, and obtained patent December 20, 1887. That they fully realized the importance of their invention, and the great future possibilities in the development of the disc piston type, is clearly shown in that part of their specifications reading as follows:

"Our invention consists in the adaptation of the oscillating action of a disk to the purpose of *positively* measuring water or other fluids, and second, in such details of construction generally as to produce a meter complete, which shall be of minimum size—requiring the least material, and involving the lowest price to construct, and yet, at the same time, maintaining the elements which shall offer the highest efficiency in points of being practically frictionless, noiseless in operation, accurate, durable and convenient to manipulate and inspect."

On October 23, 1886, James Davies, Wednesbury County of Stafford, England, obtained an English patent covering the disc action, and while it is understood that he at first intended it to be used in the construction of a motor, or engine, he filed application covering its use in meter construction, August 3, 1887, seventeen days after the date of the Thomson-Lambert filing, and obtained a patent June 5, 1888, or nearly six months after that granted Messrs. Thomson and Lambert, and from a technical standpoint there was a difference in the claims presented, as Mr. Davies specifically stated that his invention consisted chiefly "in an oscillating disc, provided with a central ball having a recess in its underside, in combination with a bearing pin which enters such recess," whereas the control of the piston movement in the Thomson-Lambert design was accomplished in an altogether different manner.

Flow Meters.

This type of meter is chiefly characterized by the entire absence of mechanical factors as far as actual measurement is concerned. The velocity of flow, transposed to the ordinary commercial volumetric units, is recorded by mechanical means, the actuating medium being a fluid pressure column which varies with the velocity of flow. The hydraulic principles involved in their construction were discovered by Henri Pitot, a noted French physicist, about 1765, and G. Venturi, an Italian physicist, about 1797, A. D. These meters are used to quite an extent, usually in connection with primary mains of very large capacity, and are undoubtedly best exemplified in the "Venturi," under patents issued to Clemens Herschel, April 17, 1888, and the "Simplex."

Compound Meters.

As the name would indicate, this type is distinguished by the compounding of a small measuring unit of the disc "piston type," and a large unit of the "current type," the operation of each being controlled by an automatic valve, thus producing a machine which is very sensitive to small flows and also providing accurate registration at heavy rates of discharge.

It may be of interest to state that the fundamental idea did not originate with Mr. Dilts, as small meters had previously been installed on by-passes around large meters in connection with back pressure valves, and that as far back as January 14, 1862, a patent was issued to Henry Isham, a description of which is given as follows:

"The invention consists in combining two or more meters by a compound valve, operated by the force of the current or water, so that the water to be discharged shall be directed to and made to pass through that meter which bears the nearest relation in capacity to the size of the stream of water discharged."

General.

Since the establishment of the United States Patent Office in 1790, nearly 700 patents have been issued on water meters, of which over 500 have been issued since 1873. They cover an almost inconceivable range in mechanical motion, detail and design and attest the fact that the meters of the present day are the product of years of unremittent study, design, experimentation and trial.

Types of Meters.

Venturi.

A Venturi meter consists of two parts, the tube and the recording instrument. The principle of the meter is based upon the relation between velocity and pressure in water flowing through a pipe of varying area; this type of meter has no mechanism in the path of the water. The readings are taken from the relative pressures in two small pipes, one leading from the pressure chamber at inlet end and the other from the throat of the tube, these pipes leading to the recording instrument.

Proportional.

A water meter of the proportional displacement type is one in which the Venturi principle has been used by coupling the main tube with a second smaller tube in such a way as to secure the same relative drop in pressure through the throats of both tubes.

The theory is that the velocity and consequent volume of flow through the smaller main will be in constant ratio to that of the larger. A displacement meter is placed in the smaller tube and the volume through the larger main computed from this reading.

Piston Meter.

The operation of a piston displacement meter may be compared to the operation of the water end of a duplex pump. There are two cylinders, in each of which a plunger moves back and forth through brass linings, carrying a slide valve over ports. Through these ports the chambers at each end of the plungers are alternately placed in connection with the inlet and discharge openings in such a manner that the water cannot pass through the meter without moving the plungers. One of the plungers operates a lever which in turn operates the counter movement through a

spindle and ratchet, moving the dial pointers once for every four strokes, or displacement of the plungers.

Current Meters.

A meter of the velocity or inferential type is one in which a reacting wheel or impeller is revolved by the current at a speed proportional to the velocity of the flow. The propellers are mounted on a vertical shaft which is carried on a bearing of agate of similar material. The water is usually divided into two parts as it enters the meter, a part passing through each propeller causing them to revolve and register the flow.

Rotary Meters.

The rotary displacement meter is one of the earliest types of meters, and was extensively used up to a few years ago, especially in the larger sizes; although the piston was constructed in various forms the principle was similar in all. The most common type was one in which the piston was constructed with alternate projections and recesses somewhat in the form of a gear, although the shape of the projections or teeth varied widely. The piston chamber was constructed with corresponding recesses and projections. The piston rolled around on these projections on one side of the case, the projections on the opposite side of piston forming a more or less tight joint with the projections of the case dividing the chamber into receiving and dividing-portions, which alternately filled and emptied as the piston revolved with the flow of water.

Disc Meters.

The principle of a nutating disc was first developed in England in connection with a rotary engine in the middle of the Nineteenth Century, and while it was a complete failure as a rotary engine the principle was successfully applied to the measurement of water, the majority of water meters now in use being of this. While there have been many modifications in the design and action of the disc, the principle is essentially the same in all applications. The disc, or piston, divides the measuring chamber into four measuring spaces, or compartments, which are alternately filled and discharged.

The water enters through the ports on the inlet side of the diaphragm and flows into the measuring spaces until the piston closes the inlet port and opens the outlet port on the opposite side of diaphragm, allowing the water to escape from the chamber. In this way the chambers above and below the piston are alternately filled and emptied during each complete nutation of the piston. The piston displacement is recorded by the dial mechanism.

Compound Meters.

Compound meters, as the name would imply, are a combination of two units designed to measure both large and small flows. The usual combination consists of a disc meter for the unit measuring small flows and a current meter for the large flows. An automatic valve mechanism

controls both meters, diverting the water through the large meter on large flows, and through the small meter on small flows.

Meters on Fire Protection Services.

Placing meters on private fire service lines should be avoided if possible, where such lines are used exclusively for fire protection, as there is danger of interrupted service if a meter is installed with any mechanism whatever that will obstruct the free flow of the water.

It is assumed that there will be no charge for water used for extinguishing fires; therefore, if the service is used for fire protection alone there is no necessity for installing a meter, unless the owner of the private fire service is suspected of using the water dishonestly. The illegitimate use of water through private fire lines appears to be the exception rather than the rule, and should be controlled by proper inspection. There should be no charge for private fire services where the expense of operating the water works plant is not increased through establishing such service, for while the private fire service is a direct benefit to the owner in that it permits of obtaining a lower rate of insurance and affords better fire protection than from the public hydrants alone, at the same time it is certainly a benefit to the water works and to the community at large, as if it fulfills its proper function less water is used for fire fighting and in congested districts the adjoining property is not endangered to such an extent as would be the case if the public hydrants only were depended upon for fire protection.

The foregoing is especially true where sprinkler systems are used, as the statistics of the National Fire Protection Association covering twenty years and 16,680 fires show that the average fire in sprinklered buildings is put out with 6.8 sprinkler heads. Assuming that each sprinkler head delivers 15 gallons per minute, which is a fair average, the amount of water discharged is 102 gallons per minute. A single standard hose stream will deliver 250 gallons per minute.

Fire Service Meters.

Contrary to a quite general understanding, the Fire Underwriters have never formally approved of any make, or type, of meter for use in connection with what are known as fire line services, their attitude being that of toleration, rather than approval. Where metering of fire service lines has been required by a Municipality, or Private Water Company, meters such as the "Trident-Protectus" or "Hersey Detector," which combine the elements of both Compound and Proportional types in a manner providing the capacity of the pipe line with little or no loss of head, are "tolerated" by the Underwriters, without prejudice to validity of rates.

Reading Meters.

Meter reading is the foundation of water bills and too much emphasis cannot be placed upon the importance of knowing that the meter readings are correct. Only familiarity with the work and with the appearance of

the dials under various conditions of moisture, dirt, etc., will enable the meter reader to do his work accurately, and accuracy is of the greatest importance in meter reading.

The straight reading indicator consists of revolving discs with figures around their periphery, revolving on a common shaft; the figures denoting the meter reading are exposed through a slot in the dial face. This type of indicator requires no instructions, as it is only necessary to copy the figures as shown.

The standard indicator consists of a train of clock gears and pinions, with pointers indicating on numbered circles or indices the figures which form the meter reading. The standard indicator is in almost general use, as it is much simpler in mechanism and is less liable to get out of order than the straight reading indicator.

(1) Before attempting to read a water meter, be sure that it is registering. If necessary turn on the water and note if the pointer of indice moves.

(2) Begin reading the meter by noting the value of the unit in which the dial reads; this is indicated by each indice. These figures indicate the value of one completed revolution of the pointers, therefore each division of an indice represents one-tenth of the amount marked against each indice. It should be noted that one complete revolution of a pointer of any indice is equal to one division of the indice of next higher value.

(3) Care must be taken to note the direction of movement of the pointers which rotate on alternate dials in opposite directions.

(4) Read the indices beginning with the one of lowest value usually marked 10 and continue in the order shown by the figures beneath each indice, setting down the figures as read, i. e., the reading of the 10 indice in the units column; that of the 100 indice in the tens column, etc.

(5) Always set down the figure on each indice that has been passed last or is just covered by the pointer, as the reading of each indice depends upon the reading of the one of next lowest value. Care must be taken when the pointer of the indice being read is close to, or covering a figure, for unless the indice of next lower value has completed a revolution, or passed the 0, the pointer which is being read has not completed the division upon which it may appear to rest and the last figure which it has entirely passed should be set down on the record.

(6) When the meter has registered its full capacity, that is, one complete revolution of the highest dial, it returns to 0 and starts again. Whenever this occurs place in front of the reading of all of the dials, the figure 1; this must be done to obtain the present reading.

(7) Dials are made to indicate cubic feet, gallons, liters or any other unit, but the great majority indicate cubic feet.

Accuracy of Meters.

The Meter Manufacturers' Exchange composed of the eight leading meter manufacturers of the United States offer the following guarantees

on the accuracy of meters and the degrees of accuracy as shown should govern the permissible variation.

Positive displacement water meters when new are guaranteed to test within the following degrees of accuracy:

⅝" meters within 2 per cent. plus, or minus, on all streams from 20 gallons per minute down to 1 gallon per minute, and within 10 per cent. minus on ¼ gallon per minute.

¾" meters within 2 per cent. plus, or minus, on all streams from 35 gallons per minute down to 2 gallons per minute, and within 10 per cent. minus on ½ gallon per minute.

1" meters within 2 per cent. plus, or minus, on all streams from 60 gallons per minute down to 3 gallons per minute, and within 10 per cent. minus on ¾ gallon per minute.

1½" meters within 2 per cent. plus, or minus, on all streams from 100 gallons per minute down to 5 gallons per minute, and within 10 per cent. minus on 1½ gallons per minute.

2" meters within 2 per cent. plus, or minus, on all streams from 160 gallons per minute down to 8 gallons per minute, and within 10 per cent. minus on 2 gallons per minute.

3" meters within 2 per cent. plus, or minus, on all streams from 320 gallons per minute down to 16 gallons per minute, and within 10 per cent. minus on 4 gallons per minute.

4" meters within 2 per cent. plus, or minus, on all streams from 560 gallons per minute down to 28 gallons per minute, and within 10 per cent. minus on 7 gallons per minute.

6" meters within 2 per cent. plus, or minus, on all streams from 960 gallons per minute down to 48 gallons per minute, and within 10 per cent. minus on 12 gallons per minute.

Testing Meters.

The correct method of testing water meters is by weighing the water, allowing 62.5 pounds of water to the cubic foot, and this method should be followed whenever possible.

The weight of water decreases as the temperature rises, the weight per cubic foot ranging from 62.42 pounds at 32 degrees Fahrenheit to 62.13 pounds at 90 degrees Fahrenheit. This will represent the ordinary range of temperature at which water is handled through meters; for all practical purposes, however, the weight of a cubic foot of water is taken at 62.5 pounds.

To ascertain the percentage of registration divide 6,250 by the number of pounds of water delivered by meter.

To determine the percentage of error in registration, multiply the error in pounds per cubic foot by 16 and divide by 10. It is necessary to run at least one complete revolution of the hand of first indice of the meter dial in all tests as the graduations of the indice may not be exact.

When necessary to make several runs to complete one revolution of the first indice, the total weight of water delivered in the several runs should be added, and in no case should a sub-division of the circle be used to calculate the accuracy of the meter. When testing a meter, a valve should be placed on the outlet side of the meter and a pressure maintained, making the conditions of test similar to that of actual service.

Where impractical to test by weight, meters may be tested in place by using a hose or pipe from the outlet of meter to a test meter placed temporarily; the test meter should, of course, be known to register accurately.

Maintenance of Meters.

The maintenance of water meters is largely a matter of inspection, testing and cleaning. The total cost of repair parts usually represents but a very small proportion of the expense of maintaining meters. For example: An 8" meter in constant service from March, 1912, until January 1, 1919, has measured 1,890,000,000 gallons of water, and during this time the only repairs necessary were repairing the agate bearing, which became loose, and renewing a worn propeller shaft and applying a new gear train. The total cost of these repair parts amounted to $7.00. The total cost of maintenance of this meter during the period above mentioned, including labor, was not more than $25.00. However, there has been a considerable expense in connection with this meter in keeping the meter and fish trap clean, as during certain seasons of the year the water carries a great deal of debris, such as leaves, etc., also small fish which clog the fish trap and interfere with the operation of the meter.

In the majority of cases where water is purchased by the meter, maintenance of the meter is handled by the City or County furnishing the water, regardless of ownership of the meter. Where meter is owned by the Water Company, the expense for maintenance is usually borne by them; if owned by the Railroad, the Railroad is either billed for the expense, or repairs made without charge, depending upon the existing agreement. In some instances a regular meter charge is made to cover all expense for testing and repairs regardless of how the expense for repairs is handled. The Railroad should know that the meter is being properly maintained, as naturally the Water Company is more likely to correct under registration than if the opposite where the case. The meter may stop entirely, or at intervals, due to poor maintenance or inspection. This means that it is necessary to render bills on an assumed consumption, that may, or may not, be correct. Therefore, in justice to both the Railroad and Water Company, the meter should be maintained as closely as possible to the same degree of accuracy as when received from the manufacturer, and to protect the Railroad's interest the maintenance of meters should have close supervision by the Railroad Water Department.

Whenever possible or practical to do so a railroad should standardize its water meters, as by so doing employees are enabled to familiarize and perfect themselves in the knowledge of the mechanical construction

which is necessary to maintain a system of meters at least expense, and greatest efficiency. It also permits of carrying a smaller stock of repair parts than would be the case where different types of meters were used.

Hot Water Meters.

There is some question as to whether a reliable device may be found for measuring hot water, except through the use of an orifice meter. This condition is not due so much to the construction of the meter as it is to the condition under which the hot water meters are required to operate. The greatest need for hot water meters is for measuring boiler feed water. Boiler feed lines, as ordinarily used, are of such size that a differential of two or three pounds developed at the pump in excess of the pressure carried on the boiler will supply all the feed water required. Hence, while meters may be working under a static pressure of from 100 to 200 pounds, the actual working head to operate the meter is possibly only two or three pounds. It will be realized that the best possible operation cannot be expected under this condition and it is not surprising that trouble has been experienced with meters on boiler feed lines. It should also be realized that the same incrustation is going on in water meters as in boilers, and while the boiler is cleaned at regular intervals, the chances are that the meter is given but little attention, notwithstanding the fact that the meter is a comparatively delicate instrument. The use of hot water meters in continued service on a boiler water line is inadvisable; for all practical purposes, occasional evaporation tests are all that are necessary, and for such purpose the ordinary hot water meter will give very good results for an indefinite period when installed on a by-pass in the boiler feed line. The inlet and outlets controlled by valves and the meter placed in operation only when evaporation tests are being conducted.

Appendix E.

FLUE FAILURES WHICH MAY BE DUE TO IMPROPER WATER CONDITIONS AND REPORT UPON METHODS OF TREATMENT TO CORRECT SUCH CONDITIONS.

R. C. BARDWELL, Chairman, Sub-Committee.

INTRODUCTION.

The operating efficiency of the modern locomotive is largely dependent upon the condition of its boiler, and to derive full service from the boiler it is necessary that water of such quality be used as will permit no liability of flue failures.

The arbitrary limit of time now allowed between flue renewals by the Federal Boiler Inspections Regulations has been raised from three to four years. This period is, at present, much longer than the ordinary life of flues, especially in the Central and Middle West territory. With the increase in size of power and the larger evaporating capacities per unit of heating surface with the greater water consumption, the flue failures caused by mineral and other agencies in the water have become more pronounced. Not only are the immediate effects of the failures serious with respect to the increased cost for boiler repairs and overtime to crews, but the intangible expense due to delays to traffic, immediate and en route, are considerable.

CHARACTER OF FAILURES.

Leaking.

The most common failures experienced are those due to leaking. These are caused principally by scale collecting at the joints of the flues and the flue sheet and hardening while the metal is hot and expanded. Consequently when cooling takes place and the sheets contract, there will be no contraction in the hard scale and the joints are opened.

Pitting.

Other failures which are becoming increasingly frequent of late are those due to pitting. These are usually the result of "scab-pitts" or local corrosion working through the metal in spots. As a rule they are not sufficiently serious to cause a complete failure on the line, but the expense of delays and inconvenience to traffic is considerable.

Burning.

In the case of water tube boilers at stationary plants the most common flue failure is the result of bagging and blowouts. This is usually caused by sludge or sediment settling into the lower rows of tubes, baking on the bottom section, and causing a mud burn or blowout through overheating of the metal.

Causes.

In general, all waters contain similar substances in solution, although varying considerably in amounts and proportions. These are usually di-

vided for identification purposes as incrusting and non-incrusting solids. In occasional instances from mine drainage regions, free acid waters may be found. At times surface supplies carry sufficient mud and suspended matter to cause trouble. In some waters the dissolved gases, usually carbon dioxide or oxygen, but occasionally hydrogen sulphide, demand attention. However, the common constituents of the incrusting solids, namely, the carbonates and sulphates of Calcium and Magnesium, are those responsible for the large majority of flue failures attributed to water conditions.

The scale formed on the flues is of considerably varying quality, depending upon the total amount of incrusting solids and the ratio of the component radicles, together with the rate of evaporation. It is known that if the incrusting sulphate content is high, especially with a large Magnesium ratio, the scale formed will be, as a rule, hard and tenacious, and very destructive to the boiler. If, on the other hand, the predominate part is Calcium Carbonate, especially with slow evaporation, the scale will be soft and porous and more easily removed by mechanical means with less damage to the flues and boiler. A muddy water or one high in suspended matter causes trouble from baking and mud burning, but in cases of high mud and suspended matter the visible evidence of prospective trouble is continually present, urging suitable corrective steps of either filtration, sedimentation, or abandonment of the supply. High rate of evaporation will tend to bake any incrustants into a hard scale.

The causes of pitting and corrosion may be enumerated as follows:

(a) *Free Acid.*—Any water which contains free acid will cause corrosion. These are rarely encountered except in coal mining regions, but where found the action is usually severe. Organic acids as the result of trade wastes or the decay of vegetable matter are occasionally encountered.

(b) *Magnesium Salts.*—Water which contains large amounts of Magnesium salts or where the ratio of Magnesium salts to the total incrustants is high, have been found to induce pitting. The Chloride of Magnesium, although infrequently encountered, has always been recognized as a corrosive salt due to hydrolizing with Hydrochloric acid as by-product. Where the hypothetical combinations indicate the presence of much Magnesium sulphate, similar action is often noticed.

(c) *Gypsum Scale.*—Where heavy scale is produced by Calcium Sulphate, the high temperature next to the boiler iron caused by the insulating effect of the scale brings about disintegration of the scale with the resulting attack on the iron by the sulphuric anhydride liberated.

(d) *Gases.*—In some waters the carbon dioxide, either free or half bound, is given as the cause of pitting. This gas, particularly when liberated in the nascent state in the boiler, attacks the iron—forming iron carbonate, an unstable compound which breaks up into iron oxide and further nascent carbonic acid, thus causing progressive pitting in spots. Some trouble is also attributed to the dissolved oxygen in water, but

amount contained under saturation limits is so small as to make action problematical.

(e) *Oil.*—Corrosion may occur from oil scale due to the high insulating effect of the thin film, with resulting acid properties liberated through disintegration under high heat.

(f) *Galvanic or Electrolytic Action.*—When high concentration of non-incrusting solids is present in boiler waters, it is probable that the cause of corrosion when experienced is due to galvanic or electrolytic action. The concentrated salts, especially Sodium Chloride, act as electrolytes, while a piece of mill scale, slag, sulphur, manganese, etc., and a spot of pure iron on the surface of the boiler wall would form the two poles of a battery with the necessary difference in potentials, and the iron plate completing the circuit. Any difference in the chemical composition of the steel in different parts of the boiler, or difference in crystalline structure, with possible segregation due to mechanical strains or deformations such as frequently occur in punching holes or poor matching, give these different spots the opportunity of acting as the opposite poles of a galvanic cell.

(g) Absolutely pure water will also cause corrosion due to its solvent properties.

The cure of boiler troubles is, in a great measure, similar to the cure of diseases, in that each problem has a specific remedy and it is impossible to lay down general directions which will fit all cases. Boiler compounds of all natures have been exploited, some acting mechanically, others supposedly mechanical, while others definitely chemical. A few manufacturers of boiler compounds have gone into the matter on a scientific and legitimate basis and have had considerable success in altering the scaling solids into loose non-crystalline, non-adhering sludge. However, except in exceptional instances, it is poor practice and uneconomical to make a sludge tank out of the boiler.

Where flue failures are common the water conditions should be thoroughly investigated, and it is a good general rule that at points where trouble originates the water should be properly softened and the objectionable constituents absolutely removed before the water is delivered to locomotives for steam purposes. At present prices it has been found that lime and soda ash are the least expensive chemicals which can be used to advantage, and with a water treating plant, properly operated, the harmful impurities can be precipitated and removed as sludge in the softener with a clear, soft, safe water delivered for steam purposes.

It has been found generally advisable to so adjust the treatment that a slight excess of hydrate alkalinity due to caustic soda be maintained in the boiler at all times. This precludes the formation of any hard sulphate scale; neutralizes any acid tendencies; assures absence of Magnesium compounds due to the insolubility of Magnesium Hydrate; neutralizes carbon dioxide, and minimizes the effects of galvanic action.

Appendix F.

INSTRUCTIONS FOR CARE OF WATER STATIONS.

W. C. HARVEY, Chairman, Sub-Committee.

Duties of Attendant.

The Pumper, Station Agent or other person in charge of the local water supply will be held responsible for the condition of the entire plant. His first duty will be to see that there is an ample supply of water available for locomotive use at all times.

In case of trouble that affects the water supply he must wire the Chief Dispatcher as well as the Water Service Foreman, stating fully the trouble and what is needed for repairs. He must make frequent inspection of all parts of the plant, make all repairs within his power and avoid sending for repair man except when absolutely necessary. He will be responsible for the safe keeping and economical use of supplies furnished to the water station and place orders for fuel and supplies in ample time to avoid a shutdown of the plant.

Pumphouse.

The attendant must keep pumphouse neat and clean and take every precaution against loss or damage by fire. Waste or other combustible material must not be stored in the pumphouse. Oil and gasoline must be stored outside in proper receptacles. Cinders must not be dumped close enough to the house to endanger it. Proper place must be provided for all tools and they must be returned to their proper place after using.

Machinery.

Machinery must be inspected daily and adjustments made to increase efficiency and to prevent wear or breakdown. Particular attention must be given to the packing and lubrication of all parts. Attendant must be familiar with the location and purpose of all steam and water pipes, valves, levers, etc., so that in case of accident or leaks the controlling valves may be properly used.

When ordering repair parts for any piece of machinery attendant, must always give the name of manufacturer, shop number of the machine and repair number of the part wanted.

Boilers.

Attendant must see that the boiler contains a sufficient amount of water before starting a fire and that the gage-cocks, water glass and safety valve are clean and in good condition.

Fire must be frequently cleaned of clinkers, and ashes and soot removed from flues. Ashes must not be allowed to accumulate beneath the grate.

Boiler must be washed out once a week or oftener if in the judgment of the Water Service Foreman it is necessary. Foaming is due to a dirty boiler and can be stopped by blowing down and filling with fresh

water. To blow down the boiler, first fill it to the top with water, then blow down to one gage with not over 30 lbs. of steam.

If it develops, when plant is operating, that no water appears in the water glass the valve below water column should be opened. If water then appears, the flow to the boiler can be increased; if not, fire must be pulled and boiler cooled before turning any water into it. Where more than one shift is in charge of the pumping plant each oncoming man should be notified, by the man leaving, of any defects.

Should safety valve stick and steam gage show over-pressure, draft doors should be closed and boiler allowed to cool off to pressure at which valve is supposed to work before any repairs or adjustments of the safety valve is attempted.

Oil Engines.

Attendant must be provided with a copy of and be governed by the manufacturer's printed instructions for operating the particular type of engine in his charge.

To secure economical and satisfactory operation, engines must be properly lubricated. Attendant must see that all moving parts are free from dirt, properly oiled and work easily. Lubricating oil must be fluid enough to be fed readily through the oiler. When oiler is being filled the lubricating oil should be run through a fine mesh strainer inserted in a funnel. The cover of the oiler should be in place at all times except when filling it. The oiler should be drained occasionally and washed out with gasoline. This applies also to the bearing oil cups.

The machinery to be driven should be detached from the engine until engine is in motion.

Before starting see that tank contains fuel and that a supply of cooling water is available. Thermometers are frequently provided which show the temperature of the cooling water around the cylinder. When running the thermometer should register 140 to 180 degrees Fahrenheit. The most favorable temperature will be different with different fuels and attendant should note the temperature at which operation is best and attempt to keep it reasonably close to that figure. The temperature can be held at that point by regulating the supply of water to the cylinder jacket by means of the valve provided for that purpose. The pump, piping and water jacket of the engine must be drained when engine is not in use to prevent freezing and cracking of cylinder.

Fuel for oil engine should be strained at the time storage tank is filled. In some types of engines fuel is injected into cylinder through a spray nozzle. Irregular operation may be caused by foreign matter in the oil sticking in the spray nozzle or in the check valve in the injector pump. The small hole in end of spray nozzle must be cleaned occasionally.

If a loss of compression is noticed, piston should be inspected. The piston rings should be free in their grooves. If they stick, the compression or explosion will blow past them and the combustion will be poor,

due to poor compression. Any accumulation of carbon which tends to stick to the rings should be washed out with gasoline.

Electric Motors.

Motor, control and pump should be inspected at least once each week, at which time all parts should be thoroughly cleaned, and all contact carefully inspected to see that they make and break at proper time and that contact surfaces are clean. All wearing parts should be well lubricated and special attention should be given to motor bearings. Building where motor is located should be kept clean. No papers or oily waste should be allowed to collect in switch boxes or near motor or near any electrical contact or wires.

Waste must not be used around commutator or brushes and gasoline or sandpaper must not be used to clean commutator. If motor sparks excessively the proper official should be notified.

Motor should be watched carefully for overheating. The commutator should not be allowed to become worn or grooved by the brushes.

Any displaced wire must be reported. No attachments should be made to the wiring, as serious damage may be done to the equipment and there is danger of personal injury. A fuse must never be replaced with anything but a proper fuse. If one of a higher ampere rating is used it may cause serious damage to the motor. The fuse is the electrical safety valve and should no more be tampered with than a steam safety valve. A test lamp should be used to find blown fuses, thus avoiding chances of electric shocks. A gage should be applied to each alternating current motor to test the space between motor and field poles. If gage will not pass freely the bearings need immediate attention.

On pump motors controlled from a distance, the remote control starter located in the pumphouse should be inspected and tested frequently to see that it starts the motor properly. Any badly burned contact should be reported.

Water Tanks.

They should be filled at each pumping to prevent shrinkage of wooden tanks, deterioration in sheets of metal tanks, as well as to safeguard the water supply in case of accident to the pumping plant. Tank spouts and grab ropes must be maintained at standard clearance. Defects in spouts, valves or discharge pipes must be reported at once. Attendant must watch engines take water and report unnecessary waste. Damage to fixtures or appliances by engines taking water must be reported to the Water Service Foreman, giving date, train and engine number.

Water Columns.

Water columns should be inspected frequently and maintained in good working order. Lifting rods should be tightened, leaky glands repacked, locks and rollers adjusted. On double track, water columns should be swung in the direction of traffic and locks maintained in such position that they hold the water column parallel to the track.

EXAMINATION QUESTIONS FOR CARE OF BOILERS.

1. (Q.) Describe in a general way the principal parts of a steam boiler and their uses.

(A.) A *steam boiler* is a vessel used to generate steam. A *firebox* or *furnace* is provided for the combustion of fuel such as coal or wood. The *smokestack* is connected with the furnace to carry away the gases of combustion and create a draft, that is, supply the burning fuel with air. An *injector* or *feed pump* supplies the water to the boiler for the generation of steam. The *steam gage* indicates the steam pressure, while the *water glass* and *gage cocks* show the height of water in the boiler. The *safety valve* is a device attached to the boiler for the purpose of assuring its safety against explosion from excessive pressure of the steam. It automatically opens when the pressure exceeds a certain limit and closes again when the pressure has fallen slightly.

2. (Q.) What is essential for the safety of a steam boiler?

(A.) A safe head of water in the boiler and a safety valve properly set and in good order.

3. (Q.) What is necessary for the proper burning of coal?

(A.) Clean flües and smoke connections and careful, even firing, keeping the fire open and free from clinkers and supplying it with the proper amount of air.

4. (Q.) What is the result of putting too much coal on a fire?

(A.) Incomplete combustion and black smoke and poor steaming effect.

5. (Q.) What is the result of carrying too thin a fire?

(A.) An uneven fire with too much air supply and poor steaming effect.

6. (Q.) (a) Of what does black smoke consist?
(b) How can it be prevented?

(A.) (a) Carbon and unburnt gases.
(b) By careful, even firing.

7. (Q.) What is the result of letting ashes accumulate beneath the grate?

(A.) A poor draft and generally the warping and burning of grates.

8. (Q.) What is the result of letting clinkers gather on the grate?

(A.) A poor fire and burning out of grates.

9. (Q.) For what purpose is the water glass used?

(A.) To indicate the height of water in boiler.

10. (Q.) What is the use of the blow-off cock?

(A.) To blow off the sediment in the bottom of the boiler. This assists in correcting foaming and priming.

11. (Q.) How would you blow down a boiler while running with a good fire?

(A.) Never leave the blow-off valve and watch the water level in water glass.

12. (Q.) How much water should be blown down at one time while running?

(A.) Never blow off more than one gage of water while running.

13. (Q.) How would you prepare a fire to last through the night without further attention?

(A.) Clear the fire carefully, removing all clinkers and bank the fire well with wet slack coal.

14. (Q.) What is priming and foaming?

(A.) Priming is the formation of wet steam which rises with such rapidity as to violently agitate the water. Small globules of water are thrown off from the surface, mixed with the steam and are carried off with it. Foaming is an aggravated form of priming, where the water is thrown up in large quantities and carried off into the pump.

15. (Q.) How would you know when the water is foaming?

(A.) By the restless action of the water in the gage-glass.

16. (Q.) How would you stop a violent case of foaming?

(A.) Frequent blowing off of boiler and supplying it with fresh water will generally correct the trouble.

17. (Q.) If you suddenly discovered there was no water in the glass what would you do?

(A.) If a light fire draw and cool off as quickly as possible; if a heavy fire cover with wet ashes or slack coal. Never open or close any outlets of steam when water is out of sight.

18. (Q.) In starting a steam pump what would you do first?

(A.) Open all cylinder cocks on steam cylinder in order to let out condensed steam and fill the lubricator.

19. (Q.) Describe the next step.

(A.) Open the throttle valve a trifle in order to warm up the cylinder and give the condensed steam time to run out of cylinder.

20. (Q.) In case of accident to the pumping plant which affects the water supply what would be your first duty?

(A.) Wire the Chief Dispatcher and Water Foreman stating fully the trouble and what is needed for repairs and then if possible make such temporary repairs as are necessary to keep the station in service until permanent repairs are made.

21. (Q.) How should pump houses be kept?

(A.) Neat and clean and every precaution taken to prevent fire.

22. (Q.) Where should oil and waste be stored?

(A.) In metal boxes or receptacles outside the pump house.

23. (Q.) What will be your duty regarding care of water columns or pen-stocks?

(A.) See that they are properly lubricated and in good working order and that the spring locks and rollers are adjusted so that column will stand parallel to the track when not in use. See that leaky valves and glands are repacked.

24. (Q.) Describe some of your other duties?

(A.) Watch engines take water, report unnecessary waste or damage to tank or fixtures or water columns, giving date, train and engine number.

EXAMINATION QUESTIONS FOR CARE OF INTERNAL COMBUSTION ENGINES.

1. (Q.) What is an internal combustion engine?

(A.) An engine run by an explosive force applied directly to the piston. An explosive mixture composed chiefly of air, in which has been blended the fuel used, oil, gas or gasoline, introduced into the cylinder, compressed and then ignited. The expansion of the explosion which occurs in the cylinder is one of the greatest forces known and forces the piston out and the power thus generated is transmitted to the crank shaft.

2. (Q.) What is a two-cycle engine?

(A.) A two-cycle engine is one in which an explosion occurs during every revolution of the crank.

3. (Q.) What is a four-cycle engine?

(A.) A four-cycle engine is one in which an explosion occurs during every other revolution of the crank.

4. (Q.) What is a carburetor and its functions?

(A.) A carburetor is a device for forming an explosive mixture of air and gasoline or other oil. It is provided with a needle valve for gas or oil and a throttle valve for air in order that a proper mixture may be made of the air and oil.

5. (Q.) What is a needle valve?

(A.) A needle valve is used on oil feed lines; the valve proper is provided with a very fine point to keep the orifice free of obstructions and permit of a close regulation of the oil.

6. (Q.) What form of ignition is commonly used on gasoline and oil engines?

(A.) Ignitors and spark plugs on gasoline and kerosene engines and hot bulb or tube on oil engines.

7. (Q.) What is the difference between an ignitor and a spark plug?

(A.) The spark is formed on an ignitor by breaking the contact between contact points of ignitor and is commonly known as make-and-break ignition. The spark is formed on a spark plug by a vibrator which causes the spark to pass between two fixed contact points and is known as jump-spark ignition.

8. (Q.) Explain the hot bulb or tube method of ignition.

(A.) The bulb or tube is heated by a torch before starting and kept hot by the successive explosions in the engine cylinder, the temperature being regulated by the cooling water, through cylinder head.

9. (Q.) What is an explosive mixture?

(A.) An explosive mixture consists of vaporized oil and air in the proper proportions.

10. (Q.) (a) What should be the temperature of the cylinder of an engine operating on gasoline?

(b) On oil?

(A.) (a) The temperature required for a gasoline engine cylinder varies from 100 degrees to 160 degrees, depending on mixture, condition of cylinder, etc.; the temperature should not be high enough to cause pre-ignition or loss of power.

(b) To insure good combustion the temperature of an oil engine cylinder should be from 150 to 160 degrees.

11. (Q.) What are the causes of hot bearings?

(A.) Friction because of tight bearings, lack of lubrication and loose bearings, causing bearing to pound hot.

12. (Q.) What should be done to correct a hot bearing?

(A.) The bearing should be carefully adjusted to eliminate unnecessary friction and pounding and the bearing properly lubricated. Water may be used on the bearing to keep the heat below the danger point until it has become properly seated. Excessive heat will cause the bearing to expand and stick.

13. (Q.) What is the effect of too much oil in the cylinder?

(A.) If too much oil is used a slow burning mixture is formed which does not develop the power that a proper explosive mixture does, causes incomplete combustion and formation of carbon.

14. (Q.) What are some of the causes of carbonization?

(A.) Carbonization is chiefly due to insufficient heat in the combustion chamber and may be caused by an overloaded engine using more oil than the heat from the combustion chamber can vaporize. It is important to prevent carbonization that the piston rings are a perfect fit to the cylinder walls, otherwise the gases may blow by the rings causing them to become fast in the grooves of the piston.

15. (Q.) How should piston rings be loosened when stuck in the grooves of the piston?

(A.) The rings should be soaked with kerosene, loosened up and grooves carefully cleaned.

16. (Q.) How would you remove the rings?

(A.) The rings can be removed by taking three strips of tin one-half inch wide and five or six inches long, slip one strip under each end of the ring and the third strip under the middle of the ring. The ring may then be slipped out of the groove and cleaned.

17. (Q.) How would you regrind inlet and exhaust valves?
(A.) To reseat valves grind with emery and oil by revolving valve on seat until it will hold compression, carefully clean both valves and seat before starting engine.

18. (Q.) What causes knocking in an engine?
(A.) Knocking may be caused by loose crank brasses, piston brasses or bearings. Loose piston rings cause a knock in the cylinder which is sometimes very hard to locate. Pre-ignition will also cause knocking in the cylinder.

19. (Q.) What causes pre-ignition?
(A.) Pre-ignition may be caused by an overload on the engine, by ignition of carbon deposit on cylinder walls and head and by the cylinder being too hot.

20. (Q.) What are the principal causes contributing to the rapid deterioration of internal combustion engines?
(A.) Lack of proper lubrication and absence of cooling water on jacket are two principal causes of the deterioration of an internal combustion engine.

Examination Questions for Care of Electrically Operated Pumps.

1. (Q.) What are the two kinds of current generated?
(A.) Direct and alternating current.

2. (Q.) How would you distinguish between the two motors?
(A.) The direct current motor will have a commutator and brushes, the alternating current motor will have neither commutator nor brushes.

3. (Q.) How should a direct current motor be started?
(A.) The arm of the starter should be moved slowly over the contacts from the "off" to the "on" position as the motor comes up to speed.

4. (Q.) How should an alternating current motor be started?
(A.) This type of motor is usually started with an auto-starter, the lever of which should be thrown first to starting position and held until motor has attained normal speed and then to the running position.

5. (Q.) What would be the result of bringing the starter handle over quickly?
(A.) The rush of current might blow a fuse, trip a circuit breaker or possibly injure the insulation of the motor windings.

6. (Q.) What is the proper method of stopping both the direct and alternating current motors?
(A.) By opening the motor switch.

7. (Q.) When using a direct current motor how should the commutators be cleaned?
(A.) With a rag moistened with signal oil.

8. (Q.) What are the indications of overheating in a motor?
(A.) A fried or charred appearance of the insulation of the windings, especially the armature.

9. (Q.) What would indicate the proper temperature of motor?
(A.) After running an hour or two the field coils and armature should be warm, but not enough to be uncomfortable to the hand.

10. (Q.) How often should motors be lubricated?
(A.) Once a month.

11. (Q.) How would you proceed to lubricate a motor?
(A.) The oil should be drained from the boxes, the boxes cleaned and refilled with clean oil.

REPORT OF COMMITTEE X—ON SIGNALS AND INTERLOCKING.

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C. C. ANTHONY,
H. E. ASTLEY,
H. S. BALLIET,
A. M. BURT,
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G. E. ELLIS,
PAUL JONES,
J. R. LEIGHTY,
W. J. ECK, *Vice-Chairman;*
J. G. M. LEISENRING,
H. K. LOWRY,
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THOS. S. STEVENS,
W. M. VANDERSLUIS,
B. WHEELWRIGHT,
R. E. WOODRUFF,

Committee.

To the American Railway Engineering Association:

Your Committee submits herewith its annual report for the year 1918.

The following subjects were assigned to your Committee by the Board of Direction:

1. Make critical examination of the subject-matter in the Manual and submit definite recommendations for changes.

2. Report on the problem of signaling railroads with reference to the effect of signaling and proper location of passing sidings on the capacity of the line.

3. Report on the specifications adopted by the Railway Signal Association which warrant endorsement, conferring with Committees 5, 6, 15, or other appropriate committees, on appliances affecting track or structures.

4. Report on the desirability of providing in connection with an automatic signal system:

   (a) An overlap.

   (b) Approach restricting speed indications.

5. Report on the various types of light signals for day and night indications.

6. Report on the feasibility of separating into distinct types of their own the signals for train operation, and the markers or signs which indicate the locations or position, or both, of information signs and switch signs for conveying information to trainmen, and design suitable for day and night (if necessary) markers or signs for switches, derailing switches, stop signs, slow signs, resume-speed signs, water-station and track-pan markers, highway crossing signals, etc.

7. Report on requisites of signal locations for automatic block signals for single-track roads.

8. Report on Automatic Train Control.

9. Report on methods in use for short circuiting track circuits for the display of signals for the protection of track workers.

10. (a) Report on applications of aspect indicating that train must take siding at a non-interlocked switch.

(b) Report on application of aspect indicating that 19 or 31 orders are to be delivered.

11. Submit a code of signal rules.

13. Investigate and report on the subject of proper time interval for the release of electrical and mechanical devices applied to signal or switch apparatus.

COMMITTEE MEETINGS.

Four meetings of the whole Committee were held during the year, two in Buffalo and two in Chicago, besides which a number of meetings were held by sub-committees.

The Track Committee requested that a member be appointed to represent this Committee at one of the meetings. This was done; Mr. J. C. Mock being appointed.

(1) REVISION OF MANUAL.

Your Committee has no recommendation for the revision of the Manual this year.

(2) REPORT ON THE PROBLEM OF SIGNALING RAILROADS WITH REFERENCE TO THE EFFECT OF SIGNALING AND PROPER LOCATION OF PASSING SIDINGS ON THE CAPACITY OF THE LINE.

The Committee submits its report in three parts under Appendix A.

In the Committee's report of 1917 it stated that "our work on this subject will be in applying and testing formulas and methods on pieces of road with actual movements of trains."

In accordance with the above statement your Committee submits in Part 1 a report on a single track railroad. Further work was done in development of a method of analysis of two or more track railroads which is submitted as Part 2, and this method was tested on a piece of railroad, results of which are given in Part 3. Recommendations of the Committee are given under the heading of Conclusions.

(3) REPORT ON THE SPECIFICATIONS ADOPTED BY THE RAILWAY SIGNAL ASSOCIATION WHICH WARRANT ENDORSEMENT, CONFERRING WITH COMMITTEES 5, 6, 15, OR OTHER APPROPRIATE COMMITTEES, ON APPLIANCES AFFECTING TRACK OR STRUCTURES.

In Appendix B your Committee submits list of matters acted upon at the Railway Signal Association convention in 1918 and adopted by letter-ballot. Recommendations on this subject are given under the heading of Conclusions.

(4) REPORT ON THE DESIRABILITY OF PROVIDING IN CONNECTION WITH AN AUTOMATIC SIGNAL SYSTEM:

(a) An overlap.

(b) Approach restricting speed indications.

On the above subject your Committee reports as follows:

(a) Overlaps are not desirable for following movements, as adequate advance information can be provided in signal system.

(b) Overlaps are necessary for opposing movements where adequate advance information cannot otherwise be provided.

Action recommended will be found under the heading of Conclusions.

(5) REPORT ON THE VARIOUS TYPES OF LIGHT SIGNALS FOR DAY AND NIGHT INDICATIONS.

In Appendix C your Committee submits a report.

Recommendations on this subject are given under the heading of Conclusions.

(6) REPORT ON SIGNS AND SIGNALS.

No progress made.

(7) REPORT ON REQUISITES OF SIGNAL LOCATIONS FOR AUTOMATIC BLOCK SIGNALS FOR SINGLE-TRACK ROADS.

Your Committee made considerable progress on this subject this year but is not yet ready to report.

(8) REPORT ON AUTOMATIC TRAIN CONTROL.

In Appendix D your Committee submits a report on this subject and its recommendations are given under the heading of Conclusions.

(9) REPORT ON METHODS IN USE FOR SHORT CIRCUITING TRACK CIRCUITS FOR THE DISPLAY OF SIGNALS FOR THE PROTECTION OF TRACK WORKERS.

No report.

(10) (a) REPORT ON APPLICATIONS OF ASPECT INDICATING THAT TRAIN MUST TAKE SIDING AT A NON-INTERLOCKED SWITCH.

(b) REPORT ON APPLICATION OF ASPECT INDICATING THAT 19 OR 31 ORDERS ARE TO BE DELIVERED.

Your Committee has made progress but is not yet ready to submit a report.

(11) SUBMIT A CODE ON SIGNAL RULES.

No report.

(13) INVESTIGATE AND REPORT ON THE SUBJECT OF PROPER TIME INTERVAL FOR THE RELEASE OF ELECTRICAL AND MECHANICAL DEVICES APPLIED TO SIGNAL OR SWITCH APPARATUS.

Considerable work has been done on the above subject but your Committee is not yet ready to report.

CONCLUSIONS.

Your Committee recommends that the following action be taken on the report submitted herewith:

2. That the matter on this subject be accepted as information.

3. That the list of Railway Signal Association specifications and standards submitted as Appendix B by this Committee in its report in 1918 be published in the Manual as supplementary to the list heretofore inserted for the information of the members.

That the submitted list of Railway Signal Association specifications and standards submitted with this report as Appendix B be published in the Manual as supplementary to the list heretofore submitted or inserted for information of the members.

4. That the Committee's report be adopted and published in the Manual.

5. That the report submitted in Appendix C be accepted as information.

8. That the report given in Appendix D be accepted as information.

RECOMMENDATIONS FOR NEXT YEAR'S WORK.

Your Committee recommends for next year's work continuation of subjects 1, 2, 3, 5, 6, 7, 8, 9, 10 and 13.

Respectfully submitted,

THE COMMITTEE ON SIGNALS AND INTERLOCKING.

Appendix A.

SUBJECT (2) REPORT ON THE PROBLEM OF SIGNALING SINGLE TRACK ROADS WITH REFERENCE TO THE EFFECT OF SIGNALING AND PROPER LOCATION OF PASSING SIDINGS ON THE CAPACITY OF THE LINE.

PART I—EFFECT OF SIDING LOCATIONS ON THE CAPACITY OF A SINGLE TRACK LINE.

In accordance with the statement made in the last report, that further work on this subject would consist of applying and testing the formulas or methods on pieces of roads, your Committee presents an analysis of the effect of passing track location on 88 miles of line.

The analysis of this line is simple, due to the fact that there are no large yards or junction points and that it is used exclusively for freight service. The traffic consists almost entirely of solid tonnage trains between yards at South Pekin and Benld. The running time of these trains, as used on Sheets 1, 2 and 3, was obtained by computation from the tractive effort of the locomotives in use, with their full theoretical tonnage for ruling grades. By the use of this method uniform results are obtained which are not possible when taking actual figures obtained by riding trains, unless the average of a large number are obtained, and the speed and time of a train at any point can be found, which is of considerable advantage in locating new passing tracks. These figures are checked by train dispatchers, and by actual figures obtained by riding several trains.

Sheet 1 is an analysis using all the present passing tracks with their present capacity, and the resultant schedule obtained is shown graphically on Sheet 4 under heading "Present A." In this and succeeding analysis the stop for water north of Womac made by all southward trains is not necessary for locomotive requirements, but is made according to rule to relieve water station at Benld.

It must be remembered that the minimum time between trains is determined by finding the maximum sum of schedules between passing sidings as shown in Column K, Sheets 1, 2, 3 and 5.

In using all the present passing tracks there are cases where they are so close together that the delayed time is large. Certain of these tracks can be left out and still maintain the same minimum time between trains (it may be advantageous to do this, even though the minimum is increased slightly), with a decrease in the delayed time to southward trains waiting for meeting. On Sheet 2 is shown an analysis using only the passing sidings which can be used to best advantage in eliminating delayed time, and the corresponding schedule is shown graphically on Sheet 4 under heading "Present B."

Sheet 3 shows the schedule as worked out under the proposed rearrangement, and which is shown graphically on Sheet 4 under the heading "Proposed." In this rearrangement the following existing tracks are to be extended to 100-car capacity, the direction of the extension being that to give the best balance of time, due consideration being given to grade, curve, highway crossings, bridges and other conditions affecting passing track location, Green Valley, Allen, Luther, Hubly, Sweetwater, Barr, Siding No. 2, Archer, Lick, Lemmon, Girard and Womac. Three new passing sidings of 100-car capacity are proposed at Bando, Mile Post 74¼ and Mile Post 94¾. In addition, Benld yard lead should be extended north into Gillespie interlocking plant, Luther passing track south into Luther interlocking plant, Lick water station moved south to the coal chute with a penstock installed between main and passing track, and a penstock similarly installed at the water station at Lemmon. This will require a total of 7.92 miles of track, but will release 2.33 miles of track at Compro, Virden and Siding No. 3 now used for passing sidings.

Sheet 5 shows a comparison of the sum of the schedules between adjacent passing sidings and the delayed time to southward trains waiting for meeting, as obtained from Columns K and L of Sheets 1, 2 and 3.

Sheet 6 shows a comparison of the capacity of main track under the different arrangements shown on Sheets 1, 2 and 3, giving in an easily comparable form the essential features and results which may be expected from the proposed rearrangement. All figures are based on the assumption that when operating at full capacity each train will meet an opposing train at each passing siding.

Sheets A and B are small scale charts of the line showing existing tracks and facilities in solid lines and proposed changes in dotted lines.

SOUTH PEKIN TO BENLD

ANALYSIS OF CAPACITY OF MAIN TRACK WITH PRESENT ARRANGEMENT "A" OF PASSING SIDINGS

	Capacity of Passing Tracks	South			North			S&N	South	South	North	S&N	
		A	B	C	D	E	F	G	H	I	J	K	L
				A+B			D+E	C+F		C+H	F	I+J	105-K
		Running Time	Coal & Water	Schedule Time–No Meeting	Running Time	Coal & Water	Schedule Time	Sum of Schedules C & F	Meeting Time	Schedule Meeting All Sidings	Schedule	Sum of Schedules	Delay Waiting for Meeting
South Pekin	Yd.												
		19		19	21		21	40	10	29	21	50	0
Green Valley	75												
		19		19	20		20	39	10 / 10	39	20	59	46
Allen	75												
		19	W 10	29	21		21	50	10 / 5	44	21	65	40
Luther	75												
		14		14	19	W 10	29	43	10 / 10	34	29	63	42
Hubly	75												
		20		20	15		15	35	10 / 10	40	15	55	50
Sweetwater	79												
Culver		16		16	17		17	33	10 / 10	36	17	53	52
Barr	75												
Tower "BX"		12		12	18		18	30	10 / 10	32	18	50	55
Siding No 2	81												
Bando		31		31	38		38	69	10 / 10	51	38	89	16
Archer	75												
		20	C&W 20	40	25		25	65	10 / 10	60	25	85	20
Lick	75												
		17		17	17	C&W 20	37	54	5 / 10	32	37	69	36
Compro	83												
		12		12	12		12	24	10 / 10	32	12	44	61
Lemmon	69												
		5		5	5		5	10	10 / 10	25	5	30	75
Virden	75												
		13		13	15		15	28	10 / 10	33	15	48	57
Girard	75												
McConn.		34	W 10	44	41		41	85	10 / 10	64	41	105 Max.	0
Womac	85												
		15		15	16		16	31	10 / 10	35	16	51	54
Siding No. 3	82												
Tower "ON"		23		23	25		25	48	10	33	25	58	0
Benld	Yd												
Totals		289	40	329	315	30	355	684	290	619	355	974	604

C = Coal
W = Water

SHEET 1 OF 6 SHEETS

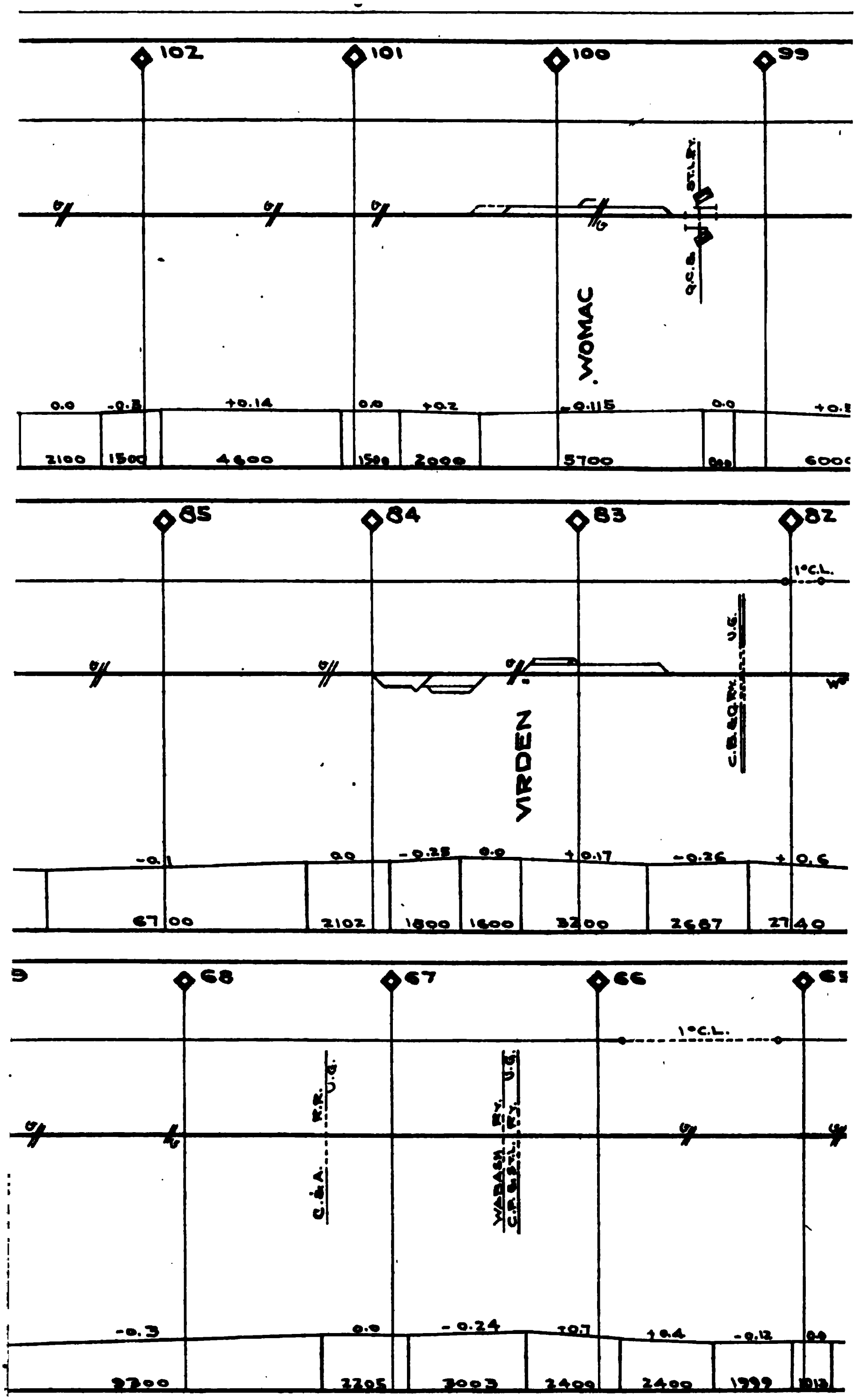
SOUTH PEKIN TO BENLD

ANALYSIS OF CAPACITY OF MAIN TRACK
WITH PRESENT ARRANGEMENT "B" OF PASSING SIDINGS.

	Capacity of Passing Tracks	South			North			S.&N.	South	South	North	S.&N.	
		A	B	C	D	E	F	G	H	I	J	K	L
				A+B			D+E	C+F		C+H	F	I+J	[illegible]
		Running Time	Coal & Water	Schedule Time - No Meeting	Running Time	Coal & Water	Schedule Time	Sum of Schedules N.&S.	Meeting Time	Schedule Meeting All Sidings	Schedule	Sum of Schedules	Delay Waiting for Meeting
South Pekin	Yd.								—				
		19		19	21		21	40		29	21	50	0
Green Valley	75								18				
Allen		38	W 10	48	41		41	89		63	41	104	1
Luther	75								18				
Hubly		34		34	34	W 10	44	78		54	44	98	7
Sweetwater	79								18				
Culver Barr Tower "BX"		28		28	35		35	63		48	35	83	22
Siding No. 2	81								18				
Bondo		31		31	38		38	69		51	38	89	16
Archer	75								18				
		20	C+W 20	40	25		25	65		60	25	85	20
Lick	75								18				
Compro		29		29	29	C+W 20	49	78		44	49	93	12
Lemmon	69								18				
Virden		18		18	20		20	38		38	20	58	47
Girard	75								18				
M C.Conn.		34	W 10	44	41		41	85		64	41	105 Max.	0
Womac	85								18				
Siding No. 3 Tower "ON"		38		38	41		41	79		48	41	89	0
Benld	Yd								—				
TOTALS		289	40	329	325	30	355	684	170	499	355	854	125

C = Coal.
W = Water.

SHEET 2 OF 6 SHEETS


102
101
100
99
WOMAC
Q.C.B.
ST.L.RY.
85
84
83
82
VIRDEN
1°C.L.
C.B.&Q.RY.
U.G.
68
67
66
C.&A. R.R.
U.G.
WABASH RY.
C.P.&ST.L. RY.
U.G.
1°C.L.

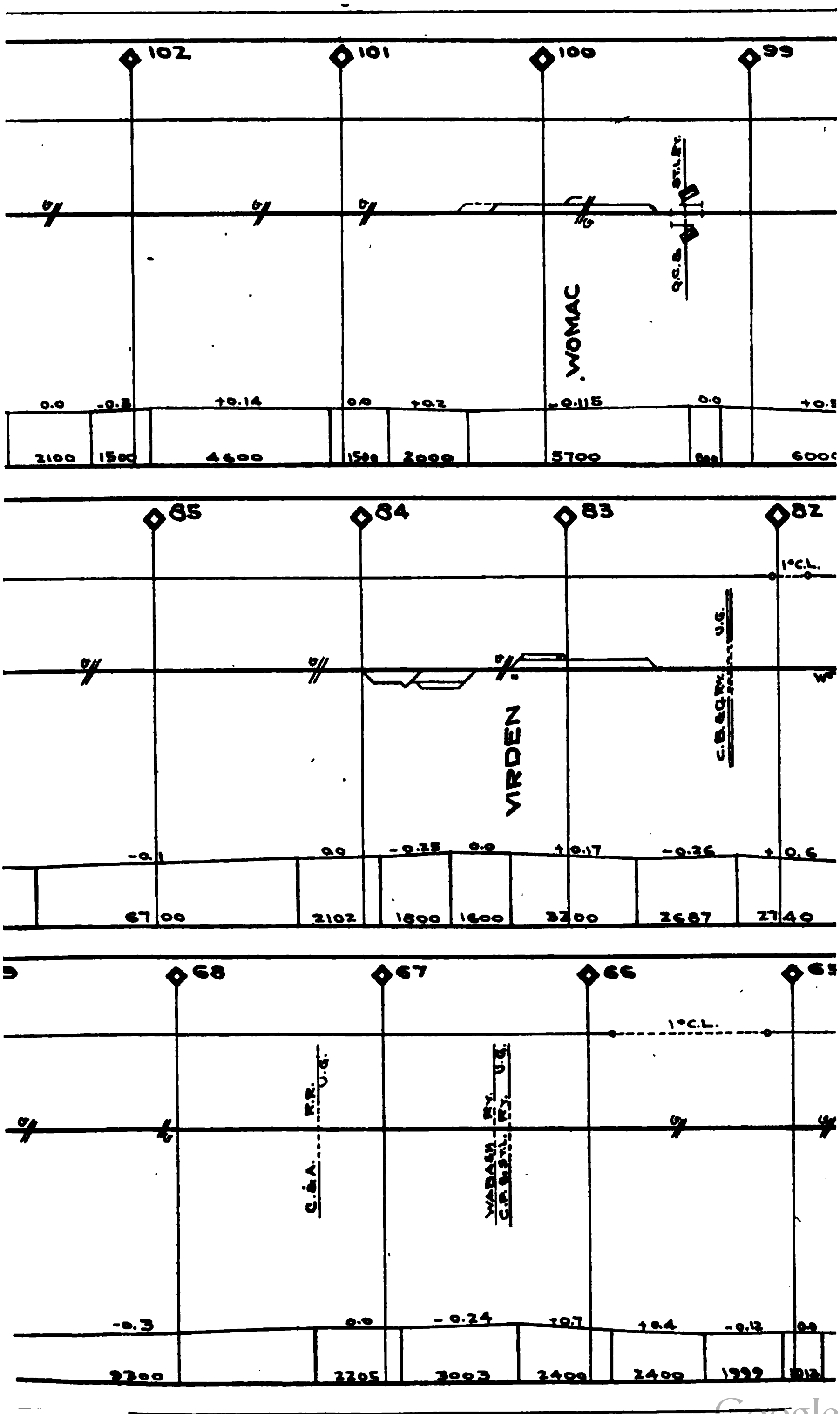
SOUTH PEKIN TO BENLD

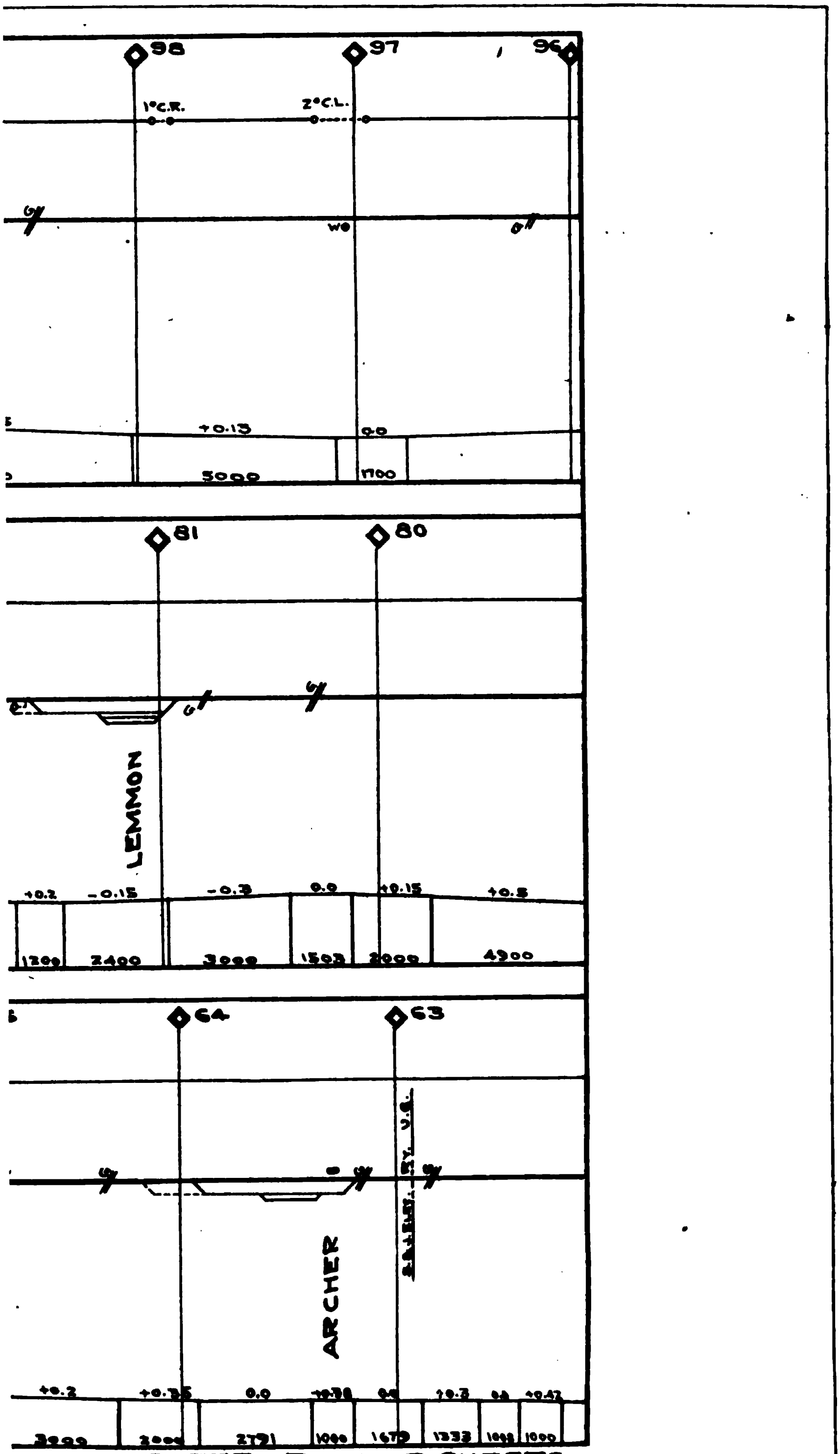
ANALYSIS OF CAPACITY OF MAIN TRACK WITH PRESENT ARRANGEMENT "B" OF PASSING SIDINGS.

	Capacity of Passing Tracks	South			North			S&N	South	South	North	S&N	
		A	B	C	D	E	F	G	H	I	J	K	L
				A+B			D+E	C+F		C+H	F	I+J	168-K
		Running Time	Coal & Water	Schedule Time - No Meeting	Running Time	Coal & Water	Schedule Time	Sum of Schedules N. & S.	Meeting Time	Schedule Meeting All Sidings	Schedule	Sum of Schedules	Delay Waiting for Meeting
South Pekin	Yd.												
		19		19	21		21	40		29	21	50	0
Green Valley	75								18				
Allen		38	W 10	48	41		41	89		63	41	104	1
Luther	75								18				
Hubly		34		34	34	W 10	44	78		54	44	98	7
Sweetwater	79								18				
Culver Barr Tower "BX"		28		28	35		35	63		48	35	83	22
Siding No. 2	81								18				
Bondo		31		31	38		38	69		51	38	89	16
Archer	75								18				
		20	C+W 20	40	25		25	65		60	25	85	20
Lick	75								18				
Compro		29		29	29	C+W 20	49	78		44	49	93	12
Lemmon	69								18				
Virden		18		18	20		20	38		38	20	58	47
Girard	75								18				
M C.Conn.		34	W 10	44	41		41	85		64	41	105 Max.	0
Womac	85								18				
Siding No. 3 Tower "ON"		38		38	41		41	79		48	41	89	0
Benld	Yd												
TOTALS		289	40	329	325	30	355	684	170	499	355	834	125

C = Coal.
W = Water.

SHEET 2 OF 6 SHEETS


102
101
100
99
WOMAC
0.0
-0.3
+0.14
+0.2
-0.115
2100
1500
4600
2000
5700
85
84
83
82
1°C.L.
VIRDEN
U.G.
-0.1
0.0
-0.28
+0.17
-0.36
+0.6
6700
2102
1800
1600
3200
2687
2740
68
67
66
1°C.L.
R.R.
U.G.
WABASH RY.
-0.3
0.0
-0.24
+0.7
+0.4
-0.12
9300
2205
3003
2400
2400
1999



SHEET B OF 2 SHEETS

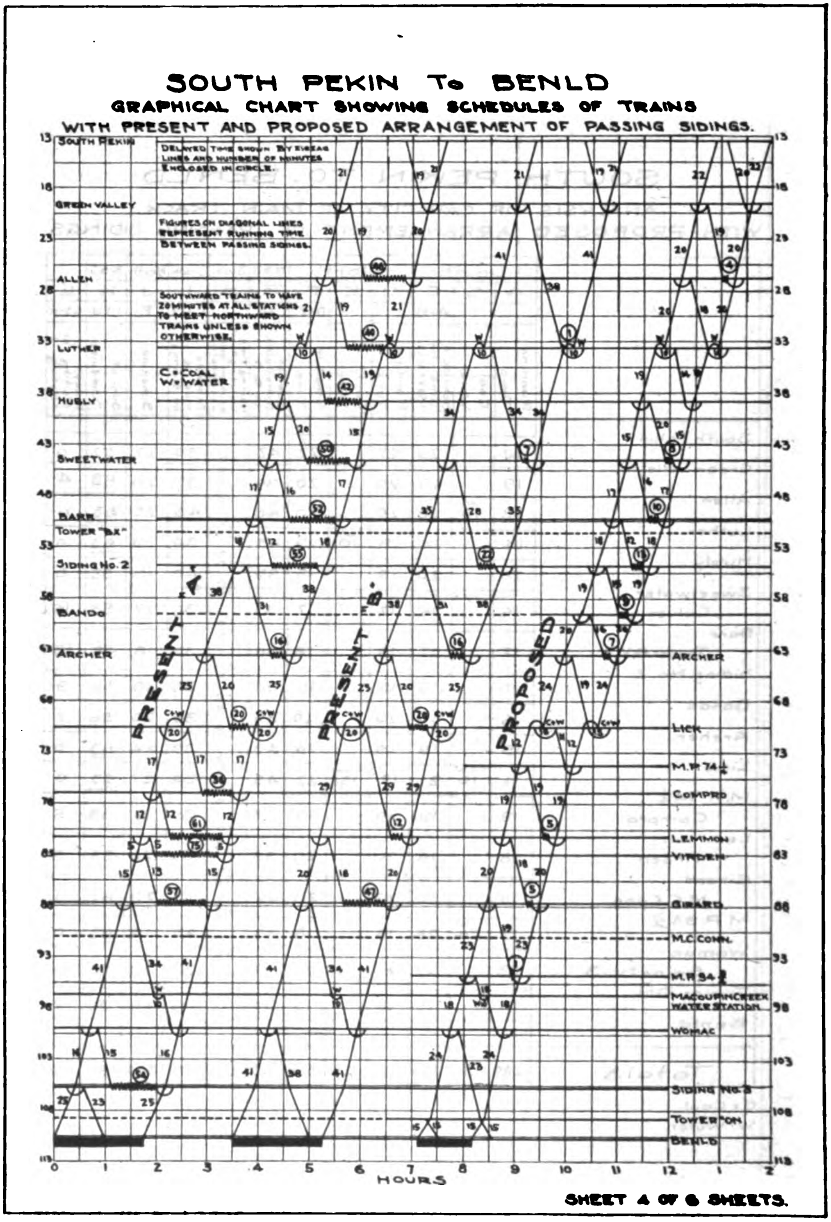
SOUTH PEKIN TO BENLD

ANALYSIS OF CAPACITY OF MAIN TRACK WITH PROPOSED ARRANGEMENT OF PASSING SIDINGS

	South			North			N.&S.	South	South	North	N.&S.	
	A	B	C	D	E	F	G	H	I	J	K	L
			A+B			D+E	C+F		C+H	F	I+J	63-K
	Running Time	Coal Water	Schedule Time—No Meeting	Running Time	Coal Water	Schedule Time	Sum of Schedules N. & S.	Waiting Time including Acceleration and Deceleration	Schedule Meeting on Sidings	Schedule	Sum of Schedules	Delay Waiting for Meeting
South Pekin, Green Valley	20		20	22		22	42	10	30	22	52	0
Allen	19		19	20		20	39	10 / 10	39	20	53	4
Luther	18	W 10	28	20		20	48	10 / 5	43	20	63 Max.	0
Hubly	14		14	18	W 10	29	43	10 / 10	34	29	63 Max.	0
Sweetwater	20		20	15		15	35	10 / 10	40	15	55	8
Culver	16		16	17		17	33	10 / 10	36	17	53	10
Barr, Tower BX	12		12	18		18	30	10 / 10	32	18	50	13
Siding No. 2	15		15	19		19	34	10 / 10	35	19	54	9
Bando	16		16	20		20	36	10 / 10	36	20	56	7
Archer	19		19	24		24	43	10 / 10	39	24	63 Max.	0
Lick	11	C W 10	21	12	C W 15	27	48	5 / 10	36	27	63 Max.	0
M.P. 74½, Compro	19		19	19		19	38	10 / 10	39	19	58	5
Lemmon, Virden	18		18	20		20	38	10 / 10	30	20	58	5
Girard, M.C.Conn.	19		19	23		23	42	10 / 10	39	23	62	1
M.P. 94½	15	W 10	25	18		18	43	10 / 10	45	18	63 Max.	0
Womac, Siding No. 3	23		23	24		24	47	10 / —	33	24	57	0
Tower ON, Benld	15		15	15		15	30	— / —	15	15	30	0
Totals	289	30	319	325	25	350	669	290	609	350	959	62

C. Coal.
W. Water.

SHEET 3 OF 6 SHEETS


SOUTH PEKIN To BENLD
GRAPHICAL CHART SHOWING SCHEDULES OF TRAINS
WITH PRESENT AND PROPOSED ARRANGEMENT OF PASSING SIDINGS.
DELAYED TIME SHOWN BY ZIGZAG LINES AND NUMBER OF MINUTES ENCLOSED IN CIRCLE.
FIGURES ON DIAGONAL LINES REPRESENT RUNNING TIME BETWEEN PASSING SIDINGS.
SOUTHWARD TRAINS TO WAIT 20 MINUTES AT ALL STATIONS TO MEET NORTHWARD TRAINS UNLESS SHOWN OTHERWISE.
C = COAL
W = WATER
SOUTH PEKIN
GREEN VALLEY
ALLEN
LUTHER
HUBLY
SWEETWATER
BARR
TOWER "BX"
SIDING No. 2
BANDO
ARCHER
LICK
M.P. 74½
COMPRO
LEMMON
VIRDEN
GIRARD
M.C. CONN.
M.P. 94.2
MACOUPIN CREEK WATER STATION
WOMAC
SIDING No. 3
TOWER "OH"
BENLD
PRESENT "A"
PRESENT "B"
PROPOSED
HOURS
SHEET 4 OF 6 SHEETS.

SOUTH PEKIN TO BENLD

COMPARISON OF SUM OF SCHEDULES AND DELAY TO TRAINS WAITING FOR MEETING.

	Present				Proposed	
	A		B			
	Using all sidings with trains that will clear on shortest siding		Using sidings to best advantage with trains that will clear on said sidings		Using all sidings as per list.	
	K	L	K	L	K	L
	Sum of Schedules	Delay waiting for meeting	Sum of Schedules	Delay waiting for meeting	Sum of Schedules	Delay waiting for meeting
South Pekin	50	0	50	0	52	0
Green Valley	59	46	104	1	59	4
Allen	65	40			63 Max.	0
Luther	63	42	98	7	63 Max.	0
Hubly	55	50			55	8
Sweetwater			83	22		
Culver	53	52			53	10
Barr						
Tower "BX"	50	55			50	13
Siding No. 2					54	9
Dando	89	16	89	16	56	7
Archer	85	20	85	20	63 Max.	0
Lick					63 Max.	0
M.P. 74¾	69	36	93	12		
Compro					58	5
Lemmon	44	61				
Virden	30	75	58	47	58	5
Girard	48	57				
Macoupin County Conn.					62	1
M.P. 94½	105 Max.	0	105 Max.	0	63 Max.	0
Womac	51	54				
Siding No. 3					57	0
Tower "ON"	58	0	89	0	30	0
Benld						
Totals	974	604	854	125	959	62

Present, column A, taken from sheet 1.
Present, column B, " " " 2.
Proposed column taken from sheet 3.

SHEET 5 OF 6 SHEETS.

SOUTH PEKIN TO BENLD

COMPARISON OF CAPACITY OF MAIN TRACK WITH VARIOUS ARRANGEMENTS OF PASSING TRACKS

		Number of trains on road at one time	Maximum sum of schedules to and from adjacent stations, including time entering and leaving sidings (See Sheet 5)	Delay to Southward Train in Minutes = sum of differences between the maximum and each individual sum of schedules to and from adjacent stations, it being considered that trains are so dispatched that there is no delayed time at terminal. (See Sheet 5)	Schedules in Minutes: Southward — Delays not included	Schedules in Minutes: Northward —	Theoretical Capacity in Trains per day including passenger.	Freight Trains: Theoretical Capacity per day.	Freight Trains: Relative Capacity	Freight Cars: Theoretical Capacity. Per day	Freight Cars: Relative Capacity.
PRESENT	A Using all siding with trains that will clear on shortest siding. (69 Cars)	16	974	604	619	355	27	27	100%	1863	100%
PRESENT	B. Using sidings which can be used to best advantage in eliminating delayed time and trains that will clear on said sidings. (69 Cars) Sidings used Green Valley, Luther, Sweetwater, Siding No 2, Archer, Lick, Lemmon, Girard, Womac	10	854	125	499	355	27	27	100%	1863	100%
PROPOSED	Proposed extension of passing sidings at Green Valley, Allen, Luther, Hubly, Sweetwater, Barr, Siding No. 2, Archer, Lick, Lemmon, Girard and Womac. New passing sidings at Benld, M.P. 74½, and M.P. 94½. All to be 100 car capacity. Extension of Benld Yard Lead North into "ON" Interlocking Plant and Luther passing siding South into Luther Interlocking Plant. Move Lick Water Station south to Coal Chute, and install Pen-stock between Main and Passing Tracks. To be followed by Automatic Signals.	17	999	62	609	350	45	45	167%	4500	242%

1863 Cars	Present "A"
1863 Cars	Present "B"
4500 Cars	Proposed.

Graphical Representation of Car Capacity

SHEET 6 OF 6 SHEETS

Part II—Effect of Siding Locations on the Capacity of a Two or More Track Line.

In the study of the effect of signaling (block signaling) and the location of passing sidings on the capacity of a track with traffic in one direction, we have quite a different problem from that of a track with traffic in both directions (see report on capacity of a single track line), for while in both cases time is the governing feature in determining how many trains can be operated between two points, in the case of a track with traffic in both directions it is the time of opposing trains which controls; whereas on a track with traffic in one direction it is the time of following trains.

The subject naturally divides itself into two parts:

(1) Proper location of passing tracks.

(2) Capacity of a line without passing tracks.

(1) Proper Location of Passing Tracks.

In order that we may have a concrete example on which to base the formulas and methods which we intend to produce, we will take a 100-mile division on which only two classes of trains are operated. First, freight trains whose running time over the division, including necessary stops for coal and water, is 6½ hours; and second, passenger trains whose running time over the division is 2½ hours. The running time of the freight train we will assume to be as follows:

From terminal A to mile post 20	66 minutes
From mile post 20 to mile post 32	30 minutes
From mile post 32 to mile post 50	54 minutes
From mile post 50 to mile post 80	105 minutes
From mile post 80 to terminal B	78 minutes
Total	333 minutes

The necessary stops for the freight train we will assume to be 12 minutes at mile post 32 for water; 33 minutes at mile post 50 for coal and water, and 12 minutes at mile post 80 for water; total time for stops being 57 minutes, so that the total time consumed on the division, as before assumed, would be 390 minutes.

The accompanying diagram shows such a freight train leaving Terminal A at 12 midnight and arriving at Terminal B at 6:30 a. m.

The passenger train leaving terminal A at 4 a. m. will arrive at terminal B at 6:30 a. m.

It is quite evident from an inspection of this diagram that if there were no passing tracks on the division, no freight trains could be operated between midnight and 4 a. m. In other words, the passenger train occupies the line for four hours. This time of four hours is equal to the difference between the running time of the freight train and the running time of the passenger train; or if we let T represent this in-

terval of time, and tF and tP represent the total running time of the freight and passenger trains respectively, we would have

$$T = tF - tP.$$

If there were no passing tracks on the division but one freight train could be operated during this interval of time. If there was one passing track on the division of only one train capacity then only one more freight train could be operated, and if there were two such passing tracks then only two more freight trains could be operated. So, the number of trains that could be operated during this interval of time would be one more than the number of passing tracks.

It is also quite evident that the maximum delay which could occur to a freight train at terminal A if there were no passing tracks would be four hours, for if it could not leave terminal A in time to reach terminal B before the passenger train, it would have to wait at terminal A until

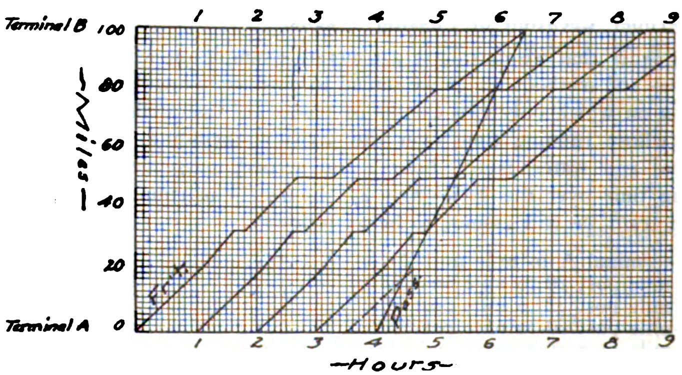


FIG. 1.—TRAIN DIAGRAM, SHOWING GRAPHIC METHOD OF LOCATING PASSING TRACKS ON DOUBLE TRACK LINES.

after the passenger train had left that terminal. Consequently, the maximum delay would also be equal to tF — tP.

It is quite evident that the proper location of passing tracks would be one that would cause the minimum amount of delay to the freight trains when they are passed by the passenger train. In order to show the conditions under which such a minimum delay will occur, we present the following diagram.

This diagram is a portion of the usual train diagram, and it shows two freight trains being passed by a passenger train at adjacent sidings. Freight train number 1 arrives at siding B at such a time in advance of the passenger train that it can clear the main line in accordance with any rules that may be in effect relative to this particular train movement. Freight train number 2 also arrives at siding A the same amount of time in advance of the passenger train. These would be the conditions

under which the minimum amount of delay would be caused to the freight trains, and that delay would be only the actual time which it is necessary for a freight train to lose due to its entering a siding to be passed by another train. This loss of time, which we will call a, may be divided into three parts, as follows: (1) The time lost by the freight train due to stopping for switch and starting again and getting into clear on the siding, which time we will call b; (2) the time the freight train must remain at rest on the siding in order to be passed by another

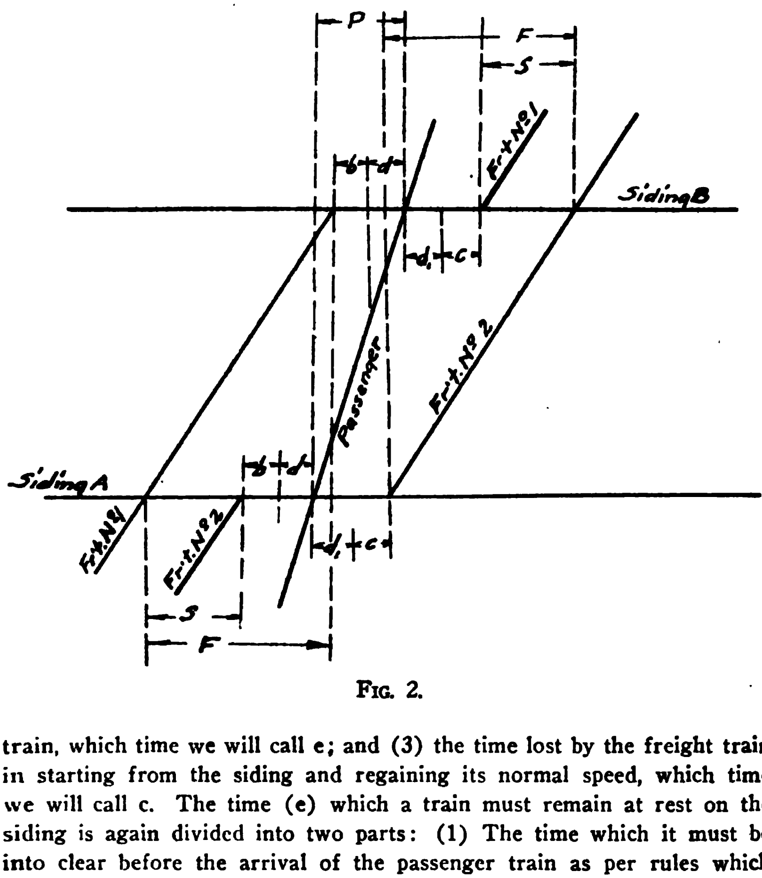


Fig. 2.

train, which time we will call e; and (3) the time lost by the freight train in starting from the siding and regaining its normal speed, which time we will call c. The time (e) which a train must remain at rest on the siding is again divided into two parts: (1) The time which it must be into clear before the arrival of the passenger train as per rules which may be in force, and (2) the time which it must remain at rest after the passenger train has passed the siding. This time also being in accordance with rules which may be in force. These two sub-divisions of the time (e) we will call d and d^1, respectively, so we would have

$$a = b + c + d + d^1$$

Representing the running time of the freight train between sidings by F, and the running time of the passenger train between the same sidings by P, we would have from the diagram

$$S = F + c + d^2 - P - d^1 - c$$

Or,

$$S = F + b + d - P - d - b$$

Or, in either case,

$$S = F - P$$

S in this case being the spacing in time between the two freight trains.

From this we learn that the minimum delay will occur to a freight train when the spacing between freight trains is equal to the difference in running time of the freight and passenger trains between the sidings. The maximum delay would occur to a freight train when, for example, freight number 1 arrived at siding A just too late to make siding B in advance of the passenger train in accordance with the rules which may be in effect, and in consequence thereof it has to wait at siding A until the passenger train had passed that siding, in which case the freight train would arrive at siding B on the time shown on the diagram for train 2. The time lost by such a delay to freight number 1 would be as shown by the diagram, equal to S, which, as heretofore shown, is $F - P$. The maximum delay is then the difference between the running times of the freight and passenger trains between the sidings, and this maximum delay will be found on a division at the point where this $F - P$ is the greatest.

Coming back now to the train diagram of our concrete example, it is quite evident that the maximum $F - P$ will be the smallest when this $F - P$ is the same for the space between each of the passing points; or, in other words, the passing tracks should be so located that the difference between the running time of a freight train and passenger train between them would all be equal, or, what is the same thing, the spacing between freight trains which are to be passed by the passenger train should be all equal.

As there is always one more space than there are passing tracks we can construct the following formulas:

$$S = \frac{tF - tP}{N + 1}$$

in which N equals the number of passing tracks. For example, if there were to be three passing tracks on the 100-mile division of our concrete example, the proper spacing between freight trains would be

$$S = \frac{390 - 150}{4}$$

Or, $S = 60$ minutes.

The proper location of this number of sidings can be easily determined graphically by laying out on the diagram freight trains leaving

terminal A one hour apart, or, at 1 o'clock, 2 o'clock and 3 o'clock, and the points where they intersect the passenger train line would be the proper location of the passing tracks, or on the diagram at mile posts 32, 50 and 80.

It will be noted from this diagram with such a location of passing tracks that the running time of a freight train between each of the passing tracks, plus the time that it is either taking water or coal, minus the running time of the passenger train between the same sidings, is in each case equal to 60 minutes. We can, therefore, establish the general rule that the proper location of passing tracks on a double track line would be such that the difference between the running time of the freight trains, including necessary stops, and the running time of the passenger trains, including necessary stops, between them should all be equal. This analysis does not take into consideration the use of the second main track for passing trains.

From the foregoing it follows that the capacity of a division is increased as the value of the time F — P is decreased. The value of this term may be decreased by either decreasing F, which would be increasing the speed of the freight trains, or by increasing P, which would be decreasing the speed of the passenger trains, and it is quite evident that the actual maximum capacity can only be reached when the value of this term is zero, in which case passing tracks would not be needed and the spacing of trains would usually be governed only by the longest time which the train is obliged to remain at rest at any point upon the division.

When all trains are running at equal speed the capacity of a division can be expressed by the simple equation,

$$Z = \frac{T}{f}$$

in which Z equals the number of trains, T an interval of time and f the interval of time between trains. If no form of block signaling is employed, this time f is determined by the maximum length of time a train is obliged to stop at any point on the division for any purpose, such as for taking coal and water, in which event the time f is equal to the amount of time which the train remains at rest for such a purpose, and the equation for capacity under these conditions becomes

$$Z = \frac{T}{D}$$

in which D equals the length of time consumed at the stop.

If the rules or a form of block signaling is used which requires a definite *time* interval between trains, then the capacity is determined by the simple equation

$$Z = \frac{T}{f}$$

but in no case can f be less than D.

In neither of these cases is the speed of trains or their length a factor in determining the capacity of a division, unless it should happen that D or f is less than the time it takes a train to travel its length. When, however, either rules or a form of block signaling is used which requires a definite *space* between trains, then the term of f depends not only upon the speed and length of trains, but also upon the length of time it requires the train to travel through the required space, and also upon two other factors which we will point out.

(2) Capacity of a Line Without Passing Tracks.

Fig. 3 shows two trains running as close together as it is possible over a block signal territory. In this figure M represents the maximum

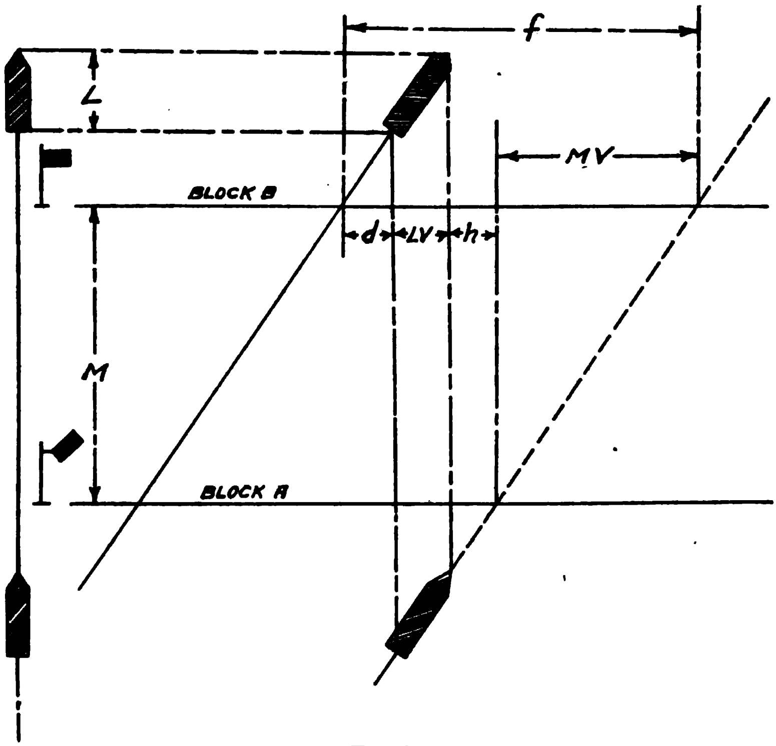


FIG. 3.

length of block in this territory and L represents the length of train. The time d is the time that must elapse after the rear end of the preceding train has passed block B before the signal at block A can be made to indicate "proceed." This time may be fixed by rule, in manual block operation or in automatic block operation it would be the time required

for the signal at block A to assume a proceed position after the rear of a train had passed into the block governed by the signal B. The time h, which is commonly called "sighting time," is the time that must be allowed for the following train to observe the signal A after it has assumed the proceed position in order that the train A may continue at its normal speed. Representing the speed of the train in miles per minute by Lv, we would have for the value of f:

$$f = h + Mv + d + Lv$$

and the equation for capacity would become

$$Z = \frac{T}{(M + L)\,v + h + d}$$

If for any reason there is a necessary stop in any block, such as a stop for coal or water, then the time lost by a train on account of such a stop must be included in the time f, and if the time f for which the block in which the stop occurs is the maximum f for the division, then this stop becomes a factor in determining the capacity of the division. In this case we would have

$$f = h + Mv + d + Lv + D$$

In this equation M is not the maximum length of block, but it is the length of block in which the delay represented by D occurs. The equation for capacity now becomes.

$$Z = \frac{T}{(M + L)\,v + h + d + D}$$

To illustrate the use of these formulas, let us determine the capacity of two pieces of road, over each of which only one class of train is operated, one of these roads being equipped with manual and the other with automatic block signaling. Let it be assumed that the trains are one-half mile long, and that they run at the rate of speed of three minutes per mile on both roads. On the manual block road assume that the maximum length of block is seven miles, and for the automatic block territory assume that the maximum spacing of signals is one mile, so that the maximum length of block for trains running under proceed signals would be two miles. In both cases let h equal one-half minute, and in manual block let d be five minutes and in automatic block one-quarter minutes. We would have then as the capacity in trains per day

For manual block,

$$Z = \frac{1440}{(7 + .5)\,3 + .5 + 5} = 51$$

For automatic block,

$$Z = \frac{1440}{(2 + .5)\,3 + .5 + .25} = 174$$

ANALYSIS OF LINE HAVING MIXED TRAFFIC.

A METHOD OF ANALYZING THE CAPACITY OF A DOUBLE TRACK LINE WHERE MIXED TRAFFIC IS OPERATED IS TO CONSIDER THE PASSENGER SCHEDULE AS FIXED AND THEN DETERMINE THE AMOUNT OF TIME THESE PASSENGER TRAINS OCCUPY THE LINE, THE REMAINING TIME BEING THAT WHICH IS AVAILABLE FOR FREIGHT TRAFFIC.

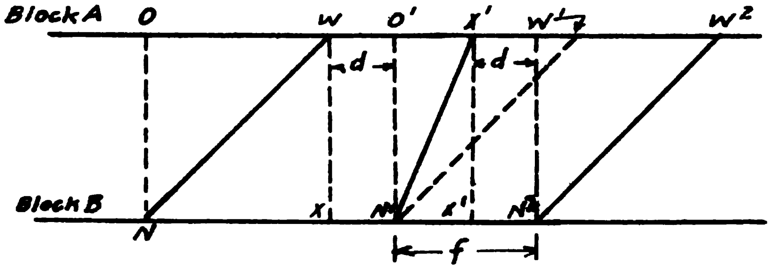


FIG. 4.

In Fig. 4 NW represents a freight train, N^1W^1 and N^2W^2 representing other trains of equal speed.

N^1X^1 represents a passenger or other train running at a greater speed.

It is obvious that f for the passenger train N^1X^1 is all that the main track capacity is reduced for freight purposes and that parallelogram N^3W^1 W^2N^2 will represent this reduction in capacity due to a single high speed train.

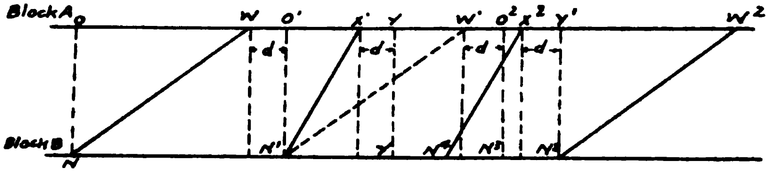


FIG. 5.

In Fig. 5, as in Fig. 4, NW represents a freight train, N^1W^1 and N^2W^2 representing other trains of equal speed.

N^1X^1, as in Fig. 4, represents a passenger train and N^4X^2 represents a second one.

From this it is obvious that when the time between two passenger trains N^1N^2 is less than f for a freight train which in this case equals N^1N^3 there is no time in which a freight train can enter the block; therefore, the total time that the main track capacity is reduced for freight purposes is passenger train time, which equals N^4N^3 plus the time between the passenger trains N^2N^4 or N^1N^2 and the amount that the main track capacity is reduced for freight purposes may be represented by the parallelogram N^3W^1 W^2N^3.

Part III—Application of Formulas for Analyzing a Two or More Track Line.

Further work on this subject has been in applying the method of analyzing the capacity of a double track line on a section of railroad 122 miles long having a heavy passenger business, there being 36 regular passenger trains in each direction at the east end, diminishing to 19 regular passenger trains in each direction at the west end.

This line is now equipped with automatic signals.

The occupancy of the main tracks by the passenger trains, both eastward and westward, was first plotted and is shown on Plates 1 and 2.

To the right on these sheets will be found the mileage between stations and there is also indicated the passing tracks and third and fourth tracks, together with the coal and water stations.

A study of the coaling locations developed that they were at places which positively fixed their locations.

Therefore, for the purposes of analysis the line naturally divides itself into five districts, the ends of which were either at a four-track junction or a coal and water station.

The method of handling each of these districts was as shown for districts from A to C on Plates 3 and 4.

Under "Present Double Track" the information from Plates 1 and 2 as to distribution of time where "main track is not available for freight service" was copied and below same the sum of the time of this interference separately between stations A and B and between B and C is shown.

The operating officials of this division have always felt that four main tracks were necessary for this district and there is no doubt that four tracks would give greater freedom of operation than three, particularly when trains are late.

A study of the capacity and delays at coal and water stations developed that 45 minutes was as close spacing as could be counted on for freight trains and on taking this into consideration, together with the necessary occupancy of the main tracks by branch line trains from Station C, it was determined that a four-track system was necessary between B and C.

It must be remembered in this connection that facilities for passing trains in both directions must be provided at the end of each district and that if a third track is determined on, the center one of which is to be used part of the time one direction and part the other, that passing tracks may be required on the other two tracks.

In the district B to C the fourth track took entire care of this feature.

An examination of the chart, Plate 3, showed that in the district between A and C the interference to eastward freight movements was between 5 a. m. and 2:20 p. m., as during the rest of the time there was no period over 45 minutes in duration when a freight train was interfered with in occupying the main track.

In the same way an examination of the chart, Plate 4, showed that the interference with freight movements was between 2:20 p. m. and 1:15 a. m. Inasmuch as there is apt to be a heavy freight movement westward in the early morning hours, it was decided to give it the advantage of a longer period of double track, particularly as this did not in any way interfere with eastward movements.

A third track was, therefore, decided on, to be operated ordinarily eastward from 3:30 a. m. to 2:20 p. m. and westward the remainder of the day.

A comparison of the "Proportion of the day main track is not available for freight service" before and after shows a reduction from 10 hours and 15 minutes to 3 hours and 30 minutes eastward and from 11 hours and 45 minutes to 3 hours and 40 minutes westward.

In like manner the various districts were analyzed and a third track with center sidings between stations G and H and between stations N and O determined on; also passing sidings at stations D and K.

The distributed interference to freight movements after the changes are made shown on Plates 5 and 6 and a comparison of the total interference before and after in each direction is shown on pages 7 and 8.

Attention is called to the fact that the total interference remaining is considerably the greatest between stations C and D westward, but an examination of page 6 shows that this interference is so thoroughly distributed through the 24 hours as to leave great freedom of operation and expenditures necessary to lessen the interference further was not warranted.

In order to obtain free use of the third and fourth tracks, automatic block signaling would have to be installed. Also new interlocking plants would be required at stations C, G, H, N and O, there being interlocking plants at the other points which can be enlarged. To reverse traffic operation controlled manual circuits should be installed between the interlocking plants at either end of the third-track systems, with an adequate system, either telegraph or telephone, of local communication between these points.

The construction of 44 miles of main track and siding, of 39 miles of automatic signaling and of five new interlocking plants, besides the enlargement of some others, would be required. The result of this would be the reduction in the interference of the use of main tracks for freight service in various territories 30 per cent. to 70 per cent. and an increase in the number of freight trains that could be handled at the most restricted point from 21 to 29 or 35 per cent. In addition to this the time of trains over the road would be considerably reduced on account of reduction in delays; the capacity of the yards at A, M and R would be greatly increased and the lost time of locomotives at these points greatly decreased account of greater freedom and better distribution of time when trains would be received and dispatched from these points.

AVAILABILITY OF MAIN TRACKS FOR FREIGHT SERVICE.

Legend.

Proportion of day main tracks are not available for freight service with present track layout.

Proportion of day main tracks are not available for freight service with proposed track layout.

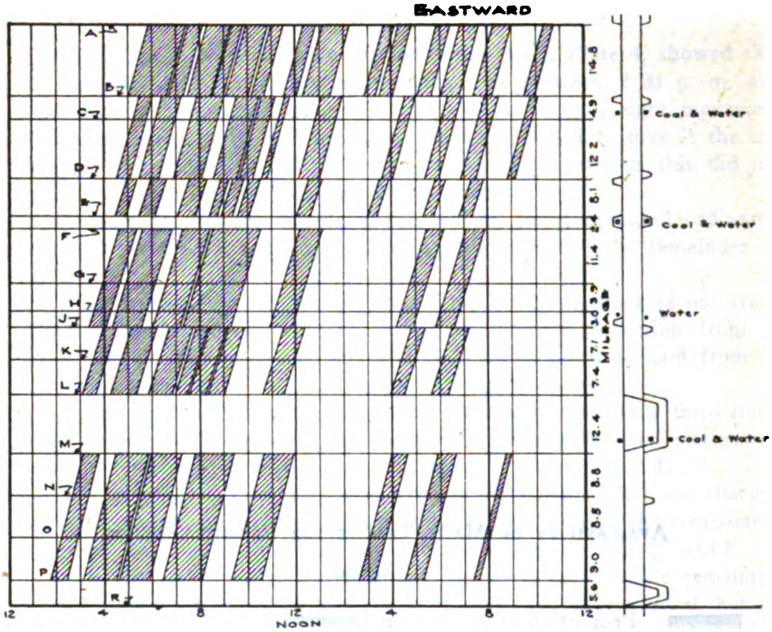
Light lines indicate Present Tracks.

Heavy lines indicate Proposed Tracks.

Present. **Plate I**

Distribution of Time When Main Track is Not Available for Freight Service.

EASTWARD



Present. **Plate II**

Distribution of Time When Main Track is Not Available for Freight Service.

WESTWARD

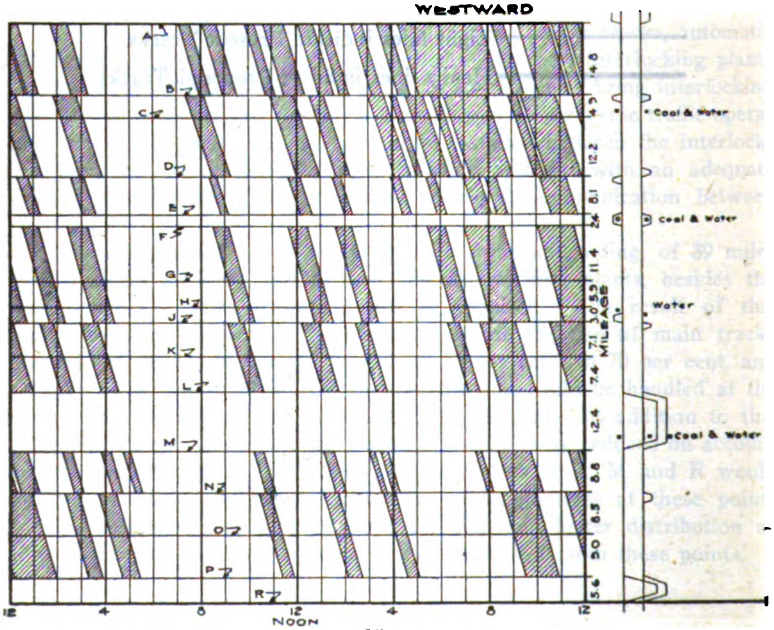


Plate IV

AVAILABILITY OF MAIN TRACKS FOR FREIGHT SERVICE.
Eastward—A to C.

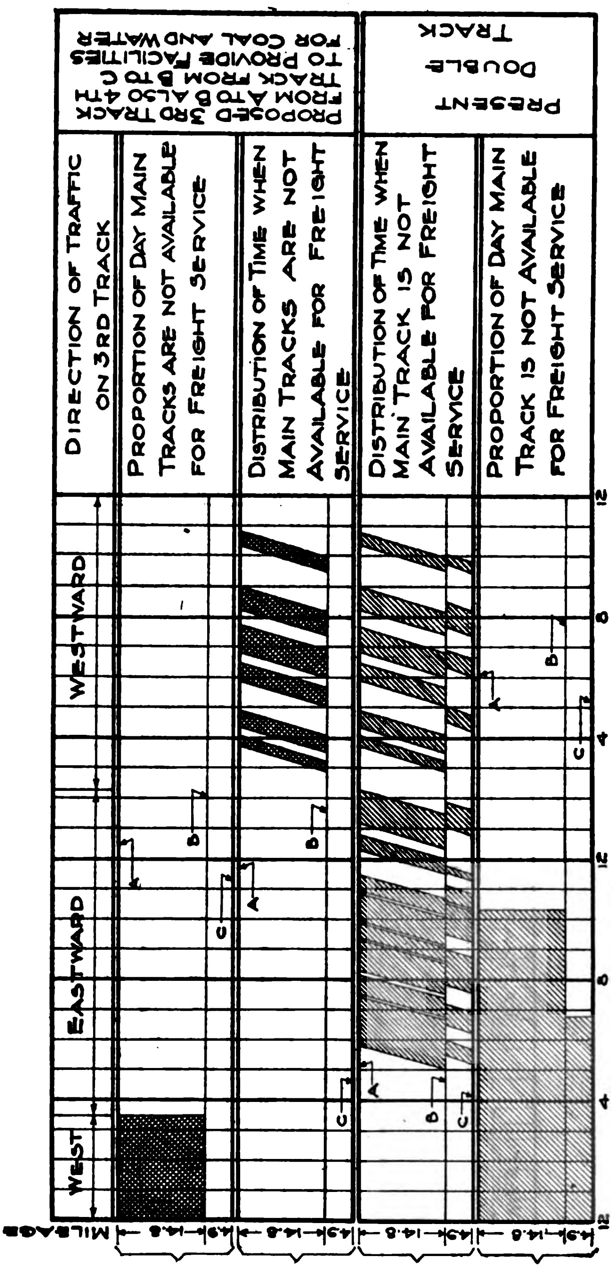
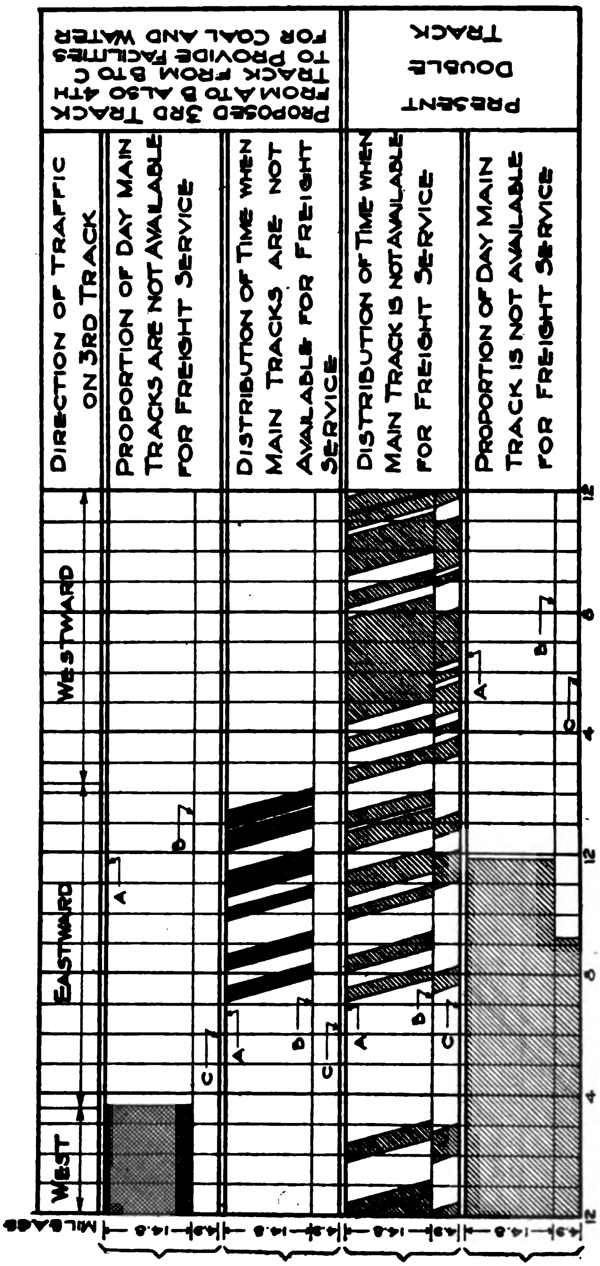


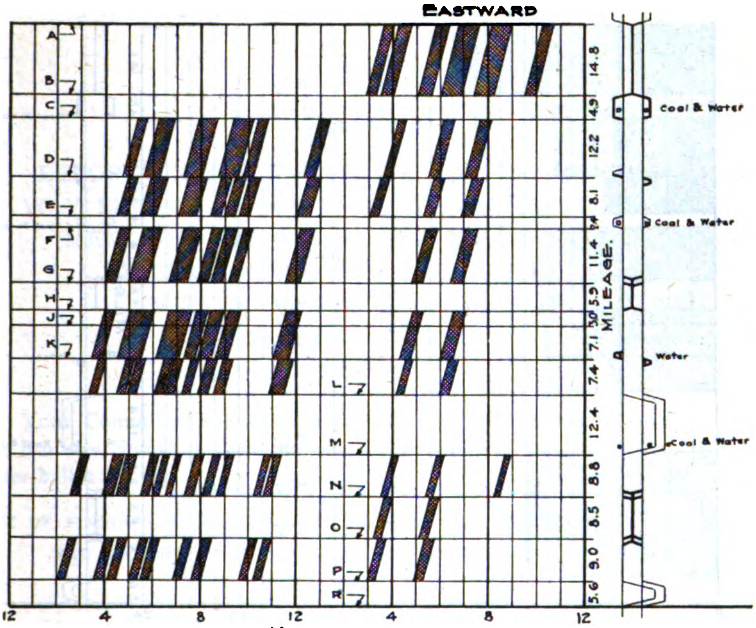
Plate III

Availability of Main Tracks for Freight Service.
Westward—C to A.



PROPOSED. **Plate V**

Distribution of Time When Main Track is Not Available for Freight Service.



PROPOSED. **Plate VI**

Distribution of Time When Main Track is Not Available for Freight Service.

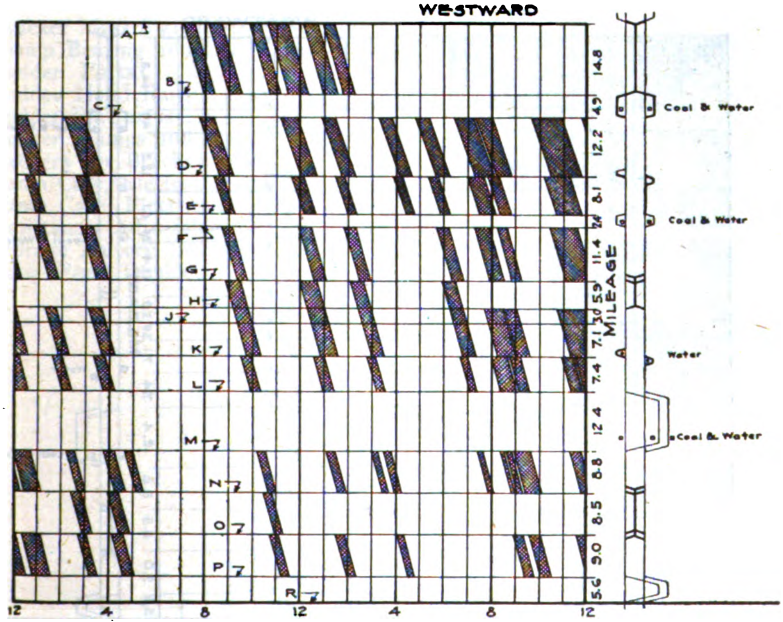


Plate VII

COMPARISON OF PROPORTION OF DAY MAIN TRACK IS AVAILABLE FOR FREIGHT SERVICE WITH PRESENT AND PROPOSED TRACK LAYOUTS.

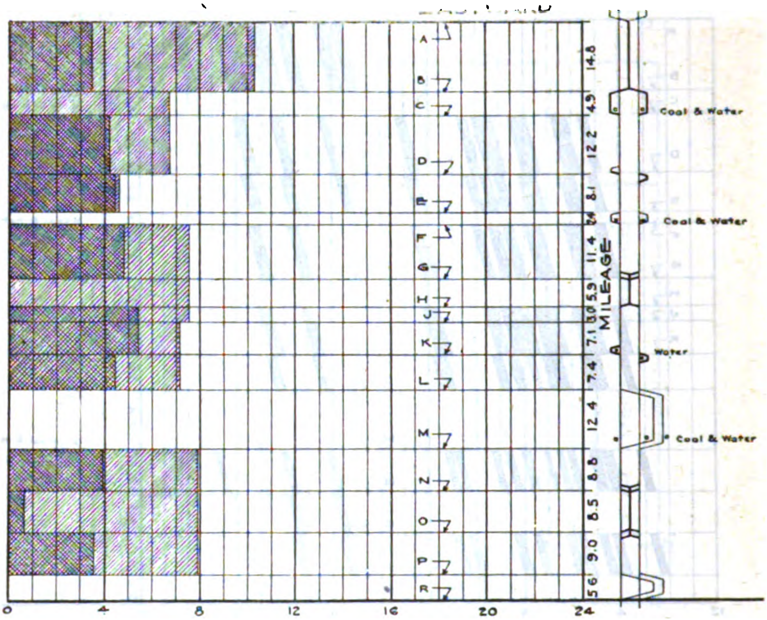
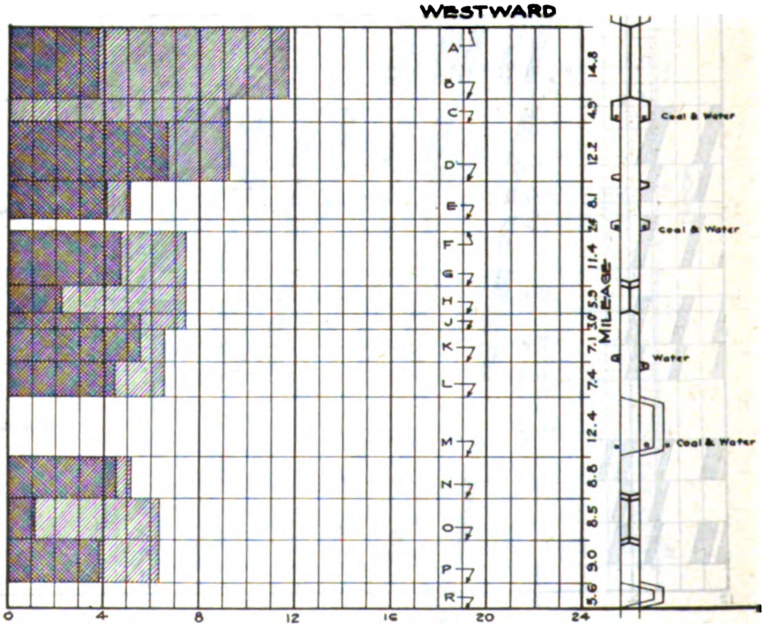


Plate VIII

COMPARISON OF PROPORTION OF DAY MAIN TRACK IS AVAILABLE FOR FREIGHT SERVICE WITH PRESENT AND PROPOSED TRACK LAYOUTS.

WESTWARD



Appendix B.

(3) REPORT ON SPECIFICATIONS ADOPTED BY THE RAILWAY SIGNAL ASSOCIATION, WHICH, IN THE JUDGMENT OF THE COMMITTEE, WARRANT CONSIDERATION, CONFERRING WITH COMMITTEE ON TRACK ON ANY APPLIANCES AFFECTING TRACK.

Your Committee submits the following list of matters acted upon by the Railway Signal Association at its convention in 1917 and adopted by letter-ballot:

LIST OF FINDINGS, CONCLUSIONS, STANDARDS AND SPECIFICATIONS ADDED TO THE MANUAL BY THE RAILWAY SIGNAL ASSOCIATION IN 1917.

TEXT.

Battery, Stationary Storage Lead Type:
Directions for installation of.

DRAWINGS.

Bracket Mast Signals, Ladders for	RSA 1366
Clamp Bearing and Clamp, for Six-Inch Pipe	RSA 1398
Ladder Parts	RSA 1362
Ladder Hand Rails	RSA 1363
Ladder Platforms	RSA 1364
Ladder Clamps and Stays	RSA 1371
Ladders for Bracket Posts	RSA 1372
Lamp Case, Electric (Details and Assembly)	RSA 1222
Lamp Case, Electric (Details)	RSA 1395
Resistance Adjustable	RSA 1422
Storage Battery Box Concrete	RSA 1433
Tang Ends Double	RSA 1376

Appendix C.

VARIOUS TYPES OF LIGHT SIGNALS FOR DAY AND NIGHT INDICATIONS.

For the purpose of this report, the following definitions apply:

1. Position light signal: A signal on which the various indications are given by positions of white lights.

2. Color light signal: A signal on which indications are given by colored lights only.

3. Position color light signals: Signals on which the indications are given by the position and color of lights.

This report covers color-light and position-light signals for day and night use.

Historical.

The following articles and reports appear in the Proceedings of the Railway Signal Association:

"Roundels," Dr. Nelson N. Black, Vol. I, p. 371.

"Roundel Problem," Dr. W. Churchill, Vol. I, p. 337.

"Optics of the Signal Lens," Dr. W. Churchill, Vol. III, p. 272.

"Signaling Installed by Philadelphia Rapid Transit Co.," page 416, Vol. 1911. Committee X.

"Electric Zone, N. Y. C. & H. R. R. R.," pp. 424 and 427, Vol. VII, 1910. Committee X.

"P. R. R. Co., Manhattan Div.," pp. 279 and 280, Vol. IX, 1912. Committee VIII.

"Metropolitan Ry. Eng.," p. 296, Vol. IX, 1912. Committee VIII.

"Underground Railways of London, England," p. 298, Vol. IX, 1912.

"Brooklyn Bridge and Terminals," pp. 305 and 306, Vol. IX, 1912. Committee VIII.

"Boston Elevated Ry. Co.," pp. 308, 310 and 312, Vol. IX, 1912. Committee VIII.

"Williamsburg Bridge and Delancey Street Terminals, New York, N. Y.," p. 463, Vol. X, 1913. Committee VIII.

"Washington, Baltimore & Annapolis Elec. Ry.," pp. 471, 473 and 474, Vol. X, 1913. Committee VIII.

"Union Traction Co. of Indiana," p. 427, Vol. XI, 1914. Committee VIII.

"Michigan Central R. R.," p. 438, Vol. XI, 1914. Committee VIII.

"Piedmont Traction Co., N. C.," p. 441, Vol. XI, 1914. Committee VIII.

"Brooklyn Rapid Transit System," pp. 444 and 453, Vol. XI, 1914. Committee VIII.

"Illumination of Signals," Mr. T. S. Stevens, p. 580, Vol. XI, 1914.

"Brooklyn Rapid Transit," pp. 406 and 407, Vol. XII, 1915. Committee VIII.

The following appear in the *Signal Engineer* and *Railway Signal Engineer* on colored-light signals:

"Penn. Term. Signals and Interlocking." March, 1912, issue, pp. 97 to 101.

"Light Signals." June, 1912, issue, p. 213.

"Inspection of Light Signals on the T. H. I. & E." August, 1912, issue, p. 281, and December, 1912, issue, p. 430.

"Aspects for Intermittent Contact Signals." March, 1913, issue, p. 82.

"Light Signal Performances." (T. H. I. & E.) April, 1913, issue, p. 136.

"Light Signals on the N. W. Pacific." January, 1914, issue, p. 12.

"Coming Into Its Own." Editorial. March, 1914, issue, p. 61.

"Light Signals and Signal Lights." Editorial. April, 1914, issue, p. 94.

"Light Signals for Day and Night Indication." April, 1914, issue, pp. 97 to 103, and May, 1914, issue, pp. 127 to 134.

"The Light Signal." Editorial. May, 1914, issue, p. 123.

"Railway Signaling and the Human Eye." May, 1914, issue, pp. 140 to 144, including copy of Dr. Black's paper on the Physiology of the Eye and Its Relation to Railway Signaling.

"Electric Light Block Signals." September, 1914, issue, p. 281.

"Light Signals for Interurban Railways." March, 1915, issue, p. 85.

"Development of Light Signals." Editorial. July, 1915, issue, p. 190. Covering colored and position-light signals.

The following covers position-light signals only:

"The Operation of Position-Light Signals," August, 1915, issue, pp. 223 to 230, and September, 1915, issue, pp. 273 to 278; also June, 1916, issue, pp. 171 to 175.

The following appear in the *Railway Age Gazette,* covering position-light signals:

January 8, 1915, p. 61; February 26, 1915, p. 366; March 5, 1915, p. 404; July 21, 1916, p. 117.

Reference may also be made to "Types of Signal Lenses," by Dr. H. P. Gage, and reports of Electric Railway Associations, etc.

General.

Three types of light signals have been designed to satisfactorily and economically meet the requirements of railroads and traction lines.

(1) A long-range signal for high speed traffic. This requires a concentrated light source, very efficient lenses and considerable care in installation and alignment.

(2) The majority of traction lines and interurban railways can use a light-signal of medium range, relatively inexpensive construction and having considerable spread to projected beam.

(3) There is another class of signaling where very short ranges are required, and where medium size and expense is the deciding factor.

In referring to these signals, we will hereafter designate them as:

Long-Range,
Medium-Range, and
Short-Range.

Long-range Signals.

In broad daylight, under unfavorable sun and background conditions, there are two alternatives open for the light source: Either a very high wattage lamp must be used, or a lower wattage with a concentrated and accurately located filament. (As illustrating the remarkable influence of concentrating the light source, we refer to the April and May, 1914, numbers of *The Signal Engineer*, where this subject is fully treated. Fig. 24 shows that a 24-watt concentrated filament lamp gives a peak candlepower of 6500, and the same wattage in a commercial lamp gives 500 candlepower. To get a long-range indication, it is necessary to project a beam candlepower of 5000 or 6000.)

The concentrated filament requires an accurate basing of the lamps so that they may be interchanged without disturbing the alignment of the signal. The automobile headlight requires refocusing when a new lamp is put in place. This cannot be done with the light signal. It would involve too much work and would also involve the employment of two experienced men to take care of realignment whenever a lamp burned out. Moreover, it is difficult, if not impossible, to obtain any very accurate adjustment for maximum candlepower in the field. Such work is properly done in a dark room. The lamps for high-speed signals are, therefore, rebased in a special jig, which permits the accurate location of the base with respect to the filament.

If a commercial concentrated filament lamp were to be used, the diameter of the filament would have to be increased to allow for commercial variations in lamp manufacture. It might be possible to design a lamp filament having sufficient concentration and yet having area enough to permit commercial variations, but, as these commercial variations permit nearly ⅛-inch departure in all directions from a theoretical filament location, the lamp wattage would have to be increased eight or nine times at least to maintain the same degree of concentration and consequently the same candlepower.

The long-range signal has a very small beam spread, on account of the concentrated filament employed. Consequently, these signals have been designed to facilitate accurate alignment by providing separate horizontal and vertical adjustments. When it is still necessary to provide some means of increasing the spread to take care of curved track, a prism lens, which spreads or "fans" the light in the horizontal plane, but which does not increase the vertical spread, is used, and the light is projected in the most efficient manner possible. (See p. 131 of the May, 1914, *Signal*

Engineer.) By means of this prism, the maximum possible range on curved track is secured with the maximum possible expenditure of power.

COLORED LIGHT SIGNALS.

Long-range Signals.

It has been found advisable, in order to increase efficiency and reduce the size of signals, to employ a double lens, by which means a large angle of the spherical candlepower of the lamp is intercepted. The outer lens used at present varies from 8⅜ inches to 10 inches.

Medium-range Signals.

In these signals the double lens is still employed to secure high efficiency, but standard lamps are used. The construction is relatively simple, as no accurate location of filament has to be provided.

Short-range Signals.

In these signals, to reduce cost, the double lens is omitted and a small lens, usually 5⅜ inches in diameter, has been substituted. In practice a 40-watt lamp with filaments of different resistance, so that one will burn out before the other, or two 25-watt lamps in multiple, are used. If fixed lights are used, so as to locate the signal if the active light is extinguished, the second lamp might be dispensed with but would be used in the fixed light. In any event, on account of the colors cutting down the range, 35 to 50 watts per light are required.

POSITION LIGHT SIGNALS.

Only two ranges are provided: Long range, 4000 to 5000 feet, for high signals, and short range, 1000 feet, more or less, for dwarf signals.

As colors are eliminated, the effective range per candlepower at the lamp is greatly increased, but special provisions have to be made for elimination of sun reflection and phantom lights; this is taken care of by special conical cover glasses, arrangement of reflectors and treatment of the inverted toric lenses, and by use and position of the spherical lamp bulb.

In practice, four 5-watt lamps are used in a row in a plane at right angles to the line of vision so that the current consumption is about one-half of that required in the colored-light signals.

The short-range signals are not hooded, but are provided with chiffon screens and frosted cover glasses. These require two 20-watt lamps, burned under voltage, or a maximum of 34 watts per signal. Experiments are now being made with the view of using same type cover glass as the high signals and reducing the wattage per signal to 10.

The high signals are equipped with 5⅜-inch lenses and cover glasses, and the dwarfs with 4 inch.

The details of construction and development may be obtained from the articles on this subject published in the *Railway Signal Engineer*, August and September, 1915, and June, 1916.

Conclusions.

(1) Colored and position-light signals, for day and night use, by elimination of all moving parts except the control relays, reduce the number of failures.

(2) Light-signal aspects have greater visibility and range under adverse weather and background conditions than the semaphore, while the close indications compare favorably.

(3) Light signals give uniform indications at all times. Other types of signals give the indication by position in daylight, by color at night, and by both during transition periods. The various aspects of the position-light signal are equal in intensity, range and visibility.

(4) In general practice, the number of aspects of any one arm of a semaphore is limited to three. With the position-light signal, four distinctive positions may be used, while the number of indications given by colored-light signals is limited only by the colors available.

(5) Where power is available, the cost of operating light signals is less than for operating motor signals.

(6) Current consumption under normal automatic signal conditions:

Position-light signals: 45-watt lamps—20 watts.

One colored light: 35 to 50 watts.

For interlocking signals, consumption is increased depending upon the number of lights displayed, but the ratio holds.

(7) Cost of maintenance of light signals is considerably less than that of motor signals, and, as the colored-light signal has less lights to renew, it has an advantage in this respect over the position-light signal.

(8) The field for the economical use of light signals is limited, as noted above, to points where power is available. In this field, the light signals have advantages over other types. The position-light signal can be installed at any location where clearance will permit the present standard semaphore to be erected. The colored-light signal can be used in more restricted clearances.

The following is submitted as supplemental information:

Three-Position Combination Semaphore and Colored Light Signal Used on the N. Y., N. H. & H. R. R. in Electrified Zone, Between New Haven and New York.

Where two-position home and distant signals were formerly in service it was necessary, on account of the catenary construction, to suspend these signals from the catenary bridges and between trolley wires. In order to procure the proper clearance and provide a signal blade of proper length, it was necessary to attach the blade to the signal in the center of same, thus making what is known as the center suspended signal. As it was desired to procure a three-position signal, it was necessary to redesign the apparatus so as to give the three indications. As the center suspended signal could not be used for this purpose, it was decided to

use the standard R. S. A. semaphore spectacle casting and attach to it a short blade. This, of course, did not give a very distinctive indication to the trainmen, and, in order to procure this indication, they developed an electric lantern with a high-powered reflector and installed it in place of the standard semaphore lamp; the result being that on account of the high candlepower light it is serviceable during the daylight hours as well as during the night, the light really predominating, the result being that the signal is commonly termed a light signal, while in reality it is a standard semaphore signal with powerful light. This signal, Mr. C. H. Morrison, their signal engineer, states, is far superior to any other signal they have tried in the territory where they operate. He further states:

"During dawn and dusk, when it is difficult to see a semaphore arm or a semaphore light, these lights are the most powerful, for the reason that during the daylight we operate on full voltage and during the night on half voltage, the voltage not being reduced until it is dark and increased as soon as daylight appears. One other advantage these signals have over signals that we have tried is that on account of the high candle power and the color of the light during extreme foggy weather the lights seem to illuminate the fog; that is, when the fog is so dense that objects can be seen but a very short distance, it is possible to see the color of the light in the fog, even though the outline of the signal on the bridge cannot be seen. On account of this signal giving such a good indication, an effort has been made to develop a signal without the semaphore apparatus that would give a similar light indication and be known as a light signal."

While they have succeeded very well in this development, they have not yet reached the stage where the details would be of general interest.

"In the combination signal 8-volt 40-watt lamps, specified to burn 1000 hours, are used—one bulb per lamp. These are operated at 7 volts (35 watts) by day and 3½ volts at night, thus increasing the life of the lamp 200 to 300 per cent. Instructions require that lamps shall be renewed every 90 days, so that an excellent light is secured during this period, as well as a large factor of safety in continuity of illumination. The reduction of voltage at night is necessary to prevent too much glare, which would otherwise be created.

"The candlepower at 7 volts is 14; at 3½ volts is 4¼; but, on account of the parabolic reflector and the lenses, the effective candlepower at 7 volts 50 feet from the unit ranges from 5500 within an arc of 2 degrees of the beam axis to 1000 candlepower within an arc of 6 degrees of the axis; that is, a spread of 12 degrees ranging from 1000 to 5500 effective candlepower. Tungsten helical filament ⅜ inch long and 5/64 inch deep, with 7 turns, is used in the bulb, which is placed in a Peter Gray lamp with 6-inch reflector."

The signals can accurately be interpreted at fairly close range. With the usual location of signals, the cab is well within the range of

the colored beams with the front of the engine at, but not beyond, the signal.

With one type of spectacle and lamp bracket, tests show that with the signal 15 feet above the eye of the engineman, that is, 25 to 30 feet above the rail, the lamp shows beneath the semaphore with signal "clear" at 24 feet 45 degrees, 15 feet and 0 degrees at less than 6 feet, while it ceases to show through the proper roundel 90 degrees at 8 feet, 45 degrees at 7 feet and 0 degrees at 6 feet. With another type of spectacle, the light shows through the roundel below (a less restricted indication than it should display) or beneath the semaphore with signal 45 degrees at 17 feet, 90 degrees at 14½ feet and 0 degrees not given; and ceases to show through the proper roundel at 0 degrees and 45 degrees, 7 feet, and at "clear" 6 feet, thus comparing very favorably with the R. S. A. standard semaphore. As far as we know this type of signal is used exclusively by the N. Y., N. H. & H. R. R. Co.

Position-Light Signal—Pennsylvania Eastern Lines Exclusively.

The development in the past year has been along the lines of interchangeability and reduced cost of construction and a further reduction in cost of maintenance and operation.

The recent adoption of the two-arm interlocking home signal as standard; in place of the three-arm, has greatly simplified the construction of the light signal by the elimination of several aspects and, consequently, of various shapes of backgrounds, by lowering signals on bridges into the bridge chords, thus doing away with ladders and platforms and permitting the use of R. S. A. standard masts for nearly all signals.

All of these features have tended to reduce the first cost, but, in addition to these changes, it has been found that a background is unnecessary for the signal light that is used for the distinctive mark of the automatic signal, and it has been eliminated. Inset shows the aspects now adopted as standard. With the signal developed by one manufacturer, the background is adjustable so that it can be used for all the three-position aspects displayed, so that for roads not using a distinctive permissive signal the two backgrounds shown for aspect No. 8 are all that are needed, the bottom background for this aspect being mounted horizontal where semaphore top arm would be fixed. The way in which the background may be turned is shown in aspect No. 6. For signals showing four positions, background No. 5 is used. The addition of No. 10 makes a maximum of four backgrounds for this system, with only two in general use.

The arms that support the light units are now removable from the grids in all new signals produced by either of the manufacturers now making them, so that changes can be made without changing the grids. Loricated conduit is bein gused for these arms by one of the makers.

It will, therefore, be seen that great progress has been made in

reduction and interchangeability of parts; with the aspects shown the use of same voltage day and night has been found entirely satisfactory. This effects a saving in expense by elimination of the wires, relays and switches formerly used for changing the voltage, while the use of the "light-out" relay makes it possible to safely use a single horizontal row for "stop," the rows in the bottom signal unit being displayed only when necessary. The practice of displaying aspect 2 on an interlocking signal instead of aspect 3, when it is desired to admit a train to an occupied track within interlocking limits in automatic block territory, is being made universal where position-light signals are used, and considerably expedites operation, as recent instructions on the road require a stop before such movement is made.

An improved lamp receptacle employing a plunger instead of a flat contact surface has demonstrated its value in always insuring a good contact.

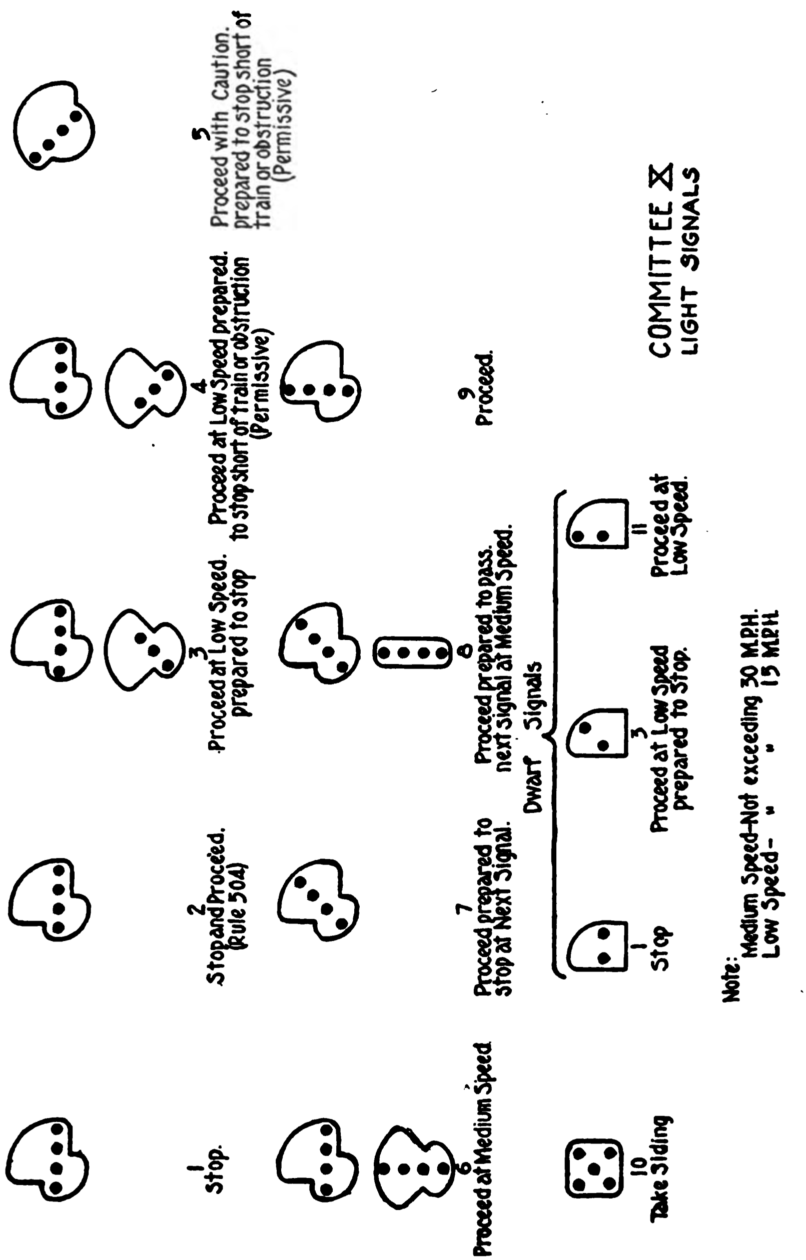
It was originally thought that "tipless" bulbs must be employed to prevent sun glare, but three years' experience has shown this was unnecessary. The bulbs with tips are a commercial product. They have, therefore, been adopted, resulting in better base sealing, more permanent vacuum, longer life, and reduced cost. The most interesting work, however, has been in connection with the filament, in an effort to obtain longer life and give more leeway in rebasing.

Naturally, with the low candlepower used, proper location of the filament in relation to the lens is absolutely necessary and is obtained by proper rebasing. Care in this one particular is most important. Lack of care results in "spotty" lights. Rebasing is done in the shop and usually by one man, and results have been good except in a few cases where an unskilled substitute for the regular man was assigned to the work. It is desirable to so design, if possible, that anyone can do this work with a minimum of instruction and skill.

As to lamp life: Records show that on the 20-mile section of four-track road with 1879 high signal light units the renewals in 1917 totaled 1453, an average effective life of 14½ months. These signals had two rows burning constantly at 11 volts or 6 volts, so that practically one-half the lamps were in service at all times, with an actual life of 7¼ months, or 5220 hours. Therefore, the lamp renewals on a three-position unit and bottom row amount to a little over 12 lamps per year at a cost for lamps and labor of rebasing of about $5.00 per annum.

By the elimination of the lower row in the new aspects, this is reduced to 8 lights at about $4.00, while by the use of the bulb with tip this is further reduced to about $3.20, where lamps are burned at 11 and 6 volts. This cost in turn will be slightly increased where the lamps are burned at about 11 volts constantly; but the average cost is conservatively figured at $3.50 per annum.

The effort is to reduce this still further by using a V-shaped filament in place of the helical coil, and experiments are being made along the


1 Stop.
2 Stop and Proceed. (Rule 504)
3 Proceed at Low Speed. prepared to stop
4 Proceed at Low Speed prepared. to stop short of train or obstruction (Permissive)
5 Proceed with Caution. prepared to stop short of train or obstruction (Permissive)
6 Proceed at Medium Speed
7 Proceed prepared to Stop at Next Signal.
8 Proceed prepared to pass. next signal at Medium Speed.
9 Proceed.
10 Take Siding
Dwarf Signals
1 Stop
3 Proceed at Low Speed prepared to Stop.
11 Proceed at Low Speed.
Note: Medium Speed-Not exceeding 30 M.P.H.
Low Speed- " " 15 M.P.H.
COMMITTEE X
LIGHT SIGNALS

lines. The filament is not as concentrated as the helical and, therefore, does not require nearly as much care in rebasing; being machine instead of hand-made is cheaper to produce; is much more rugged; and under voltage has a longer life—all decided advantages; on the other hand, being less concentrated, it must have a slightly higher candlepower with resulting increase in current; the 13-volt 9-candlepower lamps burning at 9½ volts now being tried out give a brighter light than the standard rated 12-volt 5-candlepower lamps burning at 11 volts, but are not as efficient, consuming 40 per cent. more current, although this increase is almost negligible where power is available. Probably a lower candlepower burned at around 11 volts, instead of 9½, is a better proposition.

The problem is, of course, to so balance the cost of current and the lamp renewals as to obtain the most economical proposition, which in its last analysis means saving a few cents on each light, which in the aggregate will amount to a considerable sum, as the use of this type is extended. Data at present available points to the use of helical coil for battery-fed lamps and the V-shape where power is available.

The results are not as satisfactory with the dwarf signal. With 117 units, 305 16-candlepower lamps have been renewed; two-thirds of the lamps are burning constantly, so that while the effective life of the lamps is 4½ months, the actual life is 3 months, and renewals per year per lamp cost $5.00, or, with the tip bulb, $3.75; that is, the cost of lamp renewals is greater than for a high signal.

These lamps do not require careful adjustment, and their development is along the line of lower voltage with same wattage, but burning considerably under the rated capacity, and as the current for only one lamp is broken through the relay contacts, a modified automobile lamp is well within the possibilities; this, with its rugged filament, should last a long time.

In conclusion, it may be said that no effort has been made to improve the visibility of the signal, as it is entirely satisfactory and its use is being steadily extended, the management and employes being in favor of it, but along the line of still further reducing the construction and already low maintenance costs. No false "clear" failures occurred during the year cited in this installation; in fact, none have occurred during the three years they have been in service which were chargeable to the signal, and, of course, no errors are made in reading at close range, as the aspects are clearly visible up to the signal, while in fog the angle of the light beam can be seen before the lamps themselves are distinguishable.

Colored Light Signals: One manufacturer advises that no changes of sufficient importance have been made to warrant particular mention, except that the maximum size of the outer lens for long range signals has been reduced to 6⅜-inch diameter. Another manufacturer advises:

The first published and advertised test of a light signal was conducted on the Michigan United Railway, an electric line operating out of Jackson, Michigan. This was brought about largely by a law enacted within

the State of Indiana, compelling these lines to protect their traffic with automatic signals, and the development of a light signal was a step toward economy. Prior to this test, serious consideration had not been given to a colored light signal for high speed work. The signal used at that time was made of wood and had all sorts of combination reflectors, lamps, lenses, etc., with means of securing any focus desired. They were able to get a signal which gave a satisfactory indication approximately 750 feet. From this on, it has been constantly a series of experiments with various kinds of reflectors, lamps, etc., but the greatest single element contributing to the present satisfactory colored light signal was the development of the concentrated filament incandescent lamp. Of course, the combination of lenses has contributed to the present development, but such a combination of lenses was impractical in the earlier days before the concentrated lamp was manufactured.

At the present time we do not use reflectors, as the use of a reflector was apt to cause a phantom signal when the rays from the sun or headlight penetrated the signal at a certain angle.

Considerable trouble was experienced in reading the signal at short range.

Type of Signals.

There are two general types of colored light signals:

(a) Indoor or tunnel type.

(b) Outdoor type.

The indoor type is comparatively simple, as it is used in dark or semi-light locations and only a limited range is required, hence the optical problem involved is easily solved.

The outdoor type of colored light signal presents much greater difficulties from the optical standpoint, as it must give a distinctive indication under bright sunlight conditions. This must be discernible at a range of about 3000 feet for steam road or high speed interurban electric service.

Indoor Type of Signal Units: Aspects—Signals are made up in 2 or 3-lens units to give the aspects required for two-position or three-position signaling. A two-arm signal is obtained by combining two 3-lens units.

Lenses: For indoor service a single standard optical lens of 5-inch diameter and 3½-inch focus is used of the color to give the indication desired. The lenses are usually arranged

Top—green; Middle—yellow; Bottom—red.

The same cast-iron case is used for a short-range outdoor light signal, which can be seen at a distance of about 1000 feet. This uses "double lenses."

Lamps, Incandescent: The standard arrangement is to use one lamp behind each lens. This has a double filament, having different characteristics, so as to minimize the likelihood of both burning out simultaneously. This gives a reserve effect by using only one lamp and permits of the

entire source of light to be placed on the focus of the lens. This gives a desired strength of indication with less wattage than when using two incandescent lamps in parallel behind each lens, as one of these lamps must necessarily be off focus.

Low-voltage lamps are employed as standard. These are rated at 14 volts, 10 watts, 8 candlepower, but are burned at about 10 volts. At this voltage the lamp takes about 6 watts and its life is greatly increased due to the reduced voltage at which it is burned.

The use of a low voltage lamp also gives a strong filament, which will stand rough usage without breaking. The filaments of low wattage, high-voltage tungsten lamps are quite delicate and such lamps must be handled very carefully and the percentage of breakage is high.

The lamps used for indoor signals are of the Edison medium screw base type, with an S—14 size bulb.

Outdoor Type of Signal Units. These are of two classes:

(a) Long-range class—3000 ft. range.

(b) Short-range class—1000 ft. range.

The short-range class uses the same cast-iron case as the indoor or tunnel signal, but has a special lens arrangement known as the doublet lens combination and requires higher wattage lamps than the indoor signal.

The long-range signal has larger doublet lenses than the short-range signal and takes a larger size and larger wattage incandescent lamp.

Short-Range Class of Outdoor Colored Light Signal Unit: Aspects—Each lens unit comprises two lenses, one mounted behind and close to the other. This is known as a doublet lens combination.

The outer doublet lens is a clear lens of 5-inch diameter and 2¾-inch focus. The inner doublet lens is the color specified and has a diameter of 3⅝ inches and a ⅝-inch focus. This short focus of the inner doublet enables practically all of the light from one side of the lamp filament to be collected by the inner lens, whereas a long focus lens collects only a small portion of the light from one side of the lamp filament. The incandescent lamp must be set very close to the inner doublet lens due to its short focus. For this reason, it is not practical to use two lamps behind a lens, and the double filament lamp was employed to provide a reserve light or its equivalent.

The outer doublet lens receives the light from the inner doublet and refracts it so as to give parallel rays, as the rays of light from the inner doublet lens are not parallel.

Outer doublet lenses are also made of special design, known as half toric. The steps on one side of this lens are shaped differently than for the rest of the circle or step. This bends the rays from this portion of the lens at an angle instead of giving parallel rays, and thereby increases the spread of light to one side. The toric lens can be used when signals are located on grades or curves or when it is desired to see the indication with the observer nearly opposite or underneath the signal. The

half toric portion of the lens appears as a dark spot when the observer is directly in line with the signal, but becomes light as the angle of observation is increased. The total spread of a regular 5-inch diameter outer doublet lens is about 12 degrees, or 6 inches either side of the focal axis, while the half toric lens increases the spread on one side only to about 10 degrees.

Lamps, Incandescent: A higher wattage lamp is required for the outdoor signal than for the indoor service. The short-range signal unit uses a 14-volt, 30-watt double filament lamp G-16½ clear bulb; lamp is burned at from 12 to 13 volts to give long life.

Hoods and Backgrounds: These can be furnished as a part of the signal, if conditions necessitate same. Hoods are usually required, but backgrounds have not been used to any extent, as they do not materially increase the range and are objectionable in many cases, as they make it difficult to keep the signal from infringing on the clearance available.

Long-Range Class of Outdoor Type of Colored Light Signal Unit: Lenses—Doublet lenses are employed. The outer doublet lens is 8⅜ inches in diameter and 4-inch focus, and is made of clear glass. The inner doublet lens is 5½-inch diameter and has a focal length of ½ inch. The color is as specified. The outer doublet lens can be furnished of half toric design if increased spread in one direction is required.

Lamps, Incandescent: These are 14-volt, 40-watt double filament lamps with Edison medium screw base and S—19 size bulb. Lamps are burned at from 12 to 13 volts in service.

Hoods and Backgrounds: Hoods are always supplied. Backgrounds can be furnished if required.

Lamp Adjustment: In order to take care of the variations in lamps as received from lamp manufacturers, an adjustable bracket is located in the compartment behind each lens in all types of light signal and the lamp receptacle and lamp are mounted on same. This bracket consists of three plates held together by screws. By loosening the screws any of the plates can be shifted. This permits of vertical and horizontal adjustment of the lamp so as to bring the center of its filament on the focus of the lens.

Installation of Colored Light Signals:

(a) Large numbers of indoor and short-range outdoor colored light signals have been furnished to the New York Municipal Railways.

(b) Long-range outdoor colored light signals have been furnished to the Chicago, Milwaukee & St. Paul Railway for use on their electrified divisions, and to a number of high-speed interurban trolley lines in Indiana. Colored light signals have not been used to any extent on steam roads, being required by trolley lines or electrified steam roads where alternating current power and power transmission lines are usually available.

Appendix D.

AUTOMATIC TRAIN CONTROL.

As an aid to those taking up the subject, it is desirable the following data in regard to classification of devices and reports of official tests made by the Block Signal and Train Control Board and by the Bureau of Safety, Interstate Commerce Commission of train control devices, be given as information.

The train control devices that have been tested and those that have been developed to the extent that models have been made or patents issued may be divided into the following classes or type:

1. Mechanical trip.
2. Electric contact rail.
3. Insulated track rail.
4. Magnetic inductive.
5. Inductive.
6. Hertzian wave or wireless.

DEVICES TESTED.

Rowell-Potter Safety Stop.

This included an automatic signal system, with signals operated by power stored by a passing train, and a mechanically operated train stop.

Tested on the Chicago, Burlington & Quincy Railroad, near Aurora, Ill., between December, 1908, and May, 1909. Report of test published in second annual report of Block Signal and Train Control Board.

Harrington Train Control and Alarm.

An overhead mechanical trip, and audible cab signal.

Tested on Erie Railroad, near Englewood, N. J., between January, 1910, and May, 1910. Report of test published in third annual report of Block Signal and Train Control Board.

LaCroix Train Control System.

An automatic stop and cab signal system of the intermittent contact rail type.

Tested on Staten Island Rapid Transit Railway, between March and May, 1911. Report of test published in fourth annual report of Block Signal and Train Control Board.

Warthen Cab Signal and Train Control System.

A cab signal and automatic train stop of the intermittent overhead contact type.

Tested on the Buffalo, Rochester & Pittsburgh Railway, near Rochester, N. Y., in April, 1911. Report not published.

Railway Automatic Safety Appliance Co.

An automatic stop device, of the mechanical trip type, controlled electrically.

Tested on the Pere Marquette Railroad, near Saginaw, Mich., between March and May, 1911. Report of tests published in fifth annual report of Block Signal and Train Control Board.

Jones Signal System.

An automatic train stop of the mechanical trip type, electrically controlled.

Tested on the New York Central, near LaSalle, N. Y., in March, 1913. Report not published.

Gray-Thurber Train Control System.

An automatic train control system using a short section of insulated track and an insulated portion of the train.

Tested on Pittsburgh, Fort Wayne & Chicago Railway, near Pittsburgh, in June, July and December, 1912. Also from April to July, 1914. Report published as part of the report of the Chief of the Division of Safety, Interstate Commerce Commission, for 1914, as House Document 1482, 63rd Congress, 3rd Session.

American Train Control Co.

An automatic train control system of the intermittent electrical contact type.

Tested on the Maryland & Pennsylvania Railroad, near Baltimore, in November and December, 1914. Report of tests published as House Document 1541, 63rd Congress, 3rd Session.

Gollos Railway Signal Company.

An automatic train control system of the intermittent electric contact type.

Tested on the Chicago, Burlington & Quincy Railroad, near Aurora, Ill., from August to October, 1915, and from February to April, 1916. Report of tests published as House Document 1192, 64th Congress, 1st Session.

Wooding Train Control System.

An automatic train control system of the intermittent electric contact type.

Tested on the Delaware, Lackawanna & Western Railroad, between Hoboken and Newark, N. J., in May and June, 1915, and from January to April, 1917. Report of tests published as House Document 251, 65th Congress, 1st Session.

American Train Control System.

This has been installed on the Chesapeake & Ohio Railroad on seven miles of their single track main line between Gordonsville and Cobham,

Virginia, and practically all the engines have been equipped that operate over that district. Plans are being made for some extension of the system.

This is a ramp or intermittent contact type, and is a development of the Jones System tested by the Interstate Commerce Commission on the Maryland & Pennsylvania Railroad and previously referred to in the Association Proceedings. No especially novel points of construction are indicated, but the defects existing in the old Jones System are being eliminated. Cab signals are used, but, the installation being on a piece of unsignaled track, no roadside signals exist.

Shadle Automatic Train Control.

This is a ramp or intermittent electrical contact type of train control, and was tried on the Chicago, Indianapolis & Western Railroad, near Indianapolis, although only some demonstration runs were made. There is nothing especially new in the device, and it does not vary in principle from those of this type that have been tested, but the difference is in the detail design. Standard electro-pneumatic valves are employed as relays to operate contacts for the engine circuits as well as to control the main air valves. The arrangement of circuit is such as is intended to get the desired results even should the contact with the ramp be very brief, owing to weather conditions or mechanical imperfections. The device may be used with any of the commonly used signal control circuits.

National Safety Appliance Co.

This company, of which F. F. Bostwick of San Francisco is president, has made a small installation at Oroville, Cal., on the Western Pacific Railway. It is of the induction type and consists of permanent magnets placed in the track, properly housed, with a "keeper," which is placed across the poles of the magnets by a signal movement when the block is clear. When the block is occupied, the "keeper" falls away by the releasing of the slot in the signal mechanism, leaving the magnetic field in a condition to act on the magnets carried on the engine tender. These magnets are arranged in pairs, one pair for each direction, and consist of permanent magnets holding an air valve closed. The engine magnet poles oppose those of the track magnet, so that when a track magnet, with its "keeper" up, is encountered, the magnetic field causes the armature of the engine magnet to be released, which acts on the main air valve, producing a stop. Ordinary signals are not used at Oroville, but there is no reason why they could not be, and the device made to work with any of the commonly used signal control circuits.

Schweyer Automatic Train Control.

This system is an induction scheme on rather a different principle from the other schemes of this nature which have been proposed. A coil is constantly energized by a. c. current from the engine generator, and when this passes over a piece of iron properly located on the track,

the flow of current is greatly decreased by the magnetic resistance in the coil, brought about by the iron on the track acting as an armature, and this causes the main engine relay to be de-energized, opening the circuit. If the block is clear, the engine circuit is maintained by means of direct current picked up from the track through insulated sections of the track or by special coils energized by a roadside battery placed between the rails, if electric traction prevents the use of d. c. track circuits. In this system, therefore, the induction part is used to stop the train and not to give it a clear signal, as has been proposed in other systems.

The apparatus on the track consists of the ramp acting as an armature, but it has no physical contact with the engine apparatus. It must of necessity be far enough above the rail so that it will influence the magnet and yet prevent the engine magnet from being influenced by passing over a switch lead or a double slip switch. The engine apparatus consists of four relays, all of which are of standard design with modifications to meet the conditions. The alternating current as well as the direct current employed are generated by a turbine of the same type as used for electric headlights. Transformers and condensers are used to control the current properly. The air apparatus is rather complicated, although any air valve could be used.

REPORT OF COMMITTEE II—ON BALLAST.

H. E. HALE, *Chairman;*
J. M. MEADE, *Vice-Chairman;*
C. W. BALDRIDGE,
J. S. BASSETT,
W. J. BERGEN,
THEO. BLOECHER, JR.,
H. E. BOARDMAN,
C. J. COON,
T. W. FATHERSON,
G. H. HARRIS,
F. A. JONES,
J. S. MCBRIDE,
WILLIAM MCNAB,
S. B. RICE,
H. L. RIPLEY,
PAUL STERLING,
B. B. SHAW,
F. J. STIMSON,
D. W. THROWER,
D. L. SOMMERVILLE,
W. K. WALKER,
R. C. WHITE,
W. D. WILLIAMS,

Committee.

To the American Railway Engineering Association:

The Committee submits herewith its annual report for 1919.

The subjects assigned to the Committee by the Board of Direction were as follows:

SUB-COMMITTEE No. 1.

J. M. Meade, Chairman; Special Engineer, Atchison, Topeka & Santa Fe Railway, Topeka, Kansas.

C. W. Baldridge, Asst. Engineer, Santa Fe Railway, Chicago, Ill.

B. B. Shaw, Division Engineer, Rock Island Lines, Little Rock, Ark.

F. J. Stimson, Superintendent, Pennsylvania Lines West, Richmond, Ind.

(1) Make critical examination of the subject-matter in the Manual and submit definite recommendations for changes.

(2) Recommend subjects for consideration of the Ballast Committee next year, considering the possibility of starting inquiry on this subject during the year 1918.-

SUB-COMMITTEE No. 2.

H. L. Ripley, Chairman; Corporate Chief Engineer, N. Y., N. H. & H. R. R. Co., Boston, Mass.

T. W. Fatherson (in Military Service).

G. H. Harris, Asst. Chief Engineer, Michigan Central Railroad, Detroit, Mich.

William McNab, Chairman Valuation Committee, Grand Trunk Railway, Montreal, Canada.

S. B. Rice, Engineer Maintenance of Way, Richmond, Fredericksburg & Potomac Railroad, Richmond, Va.

Paul Sterling, Maintenance Engineer, N. Y., N. H. & H. R. R., New Haven, Conn.

(1) Report on methods and comparative cost of applying ballast, giving special attention to the organization of the ballast gang.

SUB-COMMITTEE No. 3.

C. J. Coon, Chairman; Engineer Maintenance of Way, Grand Central Terminal, New York.

W. J. Bergen, Chief Corporate Engineer, New York, Chicago & St. Louis Railroad Co., Cleveland, Ohio.

H. E. Boardman, Engineering Assistant to the General Valuation Counsel, New York Central Lines, New York City.

D. L. Sommerville, Superintendent New York Central, Lines East, Rochester, N. Y.

W. D. Williams, Chief Engineer, Cincinnati Northern Railroad, Van Wert, Ohio.

Theo. Bloecher, Jr., Division Engineer, Baltimore & Ohio Railroad, Philadelphia, Pa.

(1) Study and report on design of gravel washing plants.
(2) Study and report on design of stone crushing plants.

SUB-COMMITTEE No. 4.

J. S. McBride, Chairman; Principal Assistant Engineer, Chicago & Eastern Illinois Railroad, Chicago, Ill.

J. S. Bassett (in Military Service).

F. A. Jones, General Roadmaster, Missouri Pacific Railroad, Wynne, Ark.

D. W. Thrower, Valuation Engineer, Illinois Central Railroad, Chicago, Ill.

W. K. Walker (in Military Service).

R. C. White, Assistant Chief Engineer, Missouri Pacific Railroad, St. Louis, Mo.

(1) Report on the proper depth of ballast of various kinds to insure uniform distribution of loads on the roadbed, conferring with Special Committee on Stresses in Railroad Track and Committee on Roadway.

COMMITTEE MEETINGS.

Two meetings of the General Committee were held during the year, one in New York on June 28, 1918, when five members were present, and one in Chicago on November 19, 1918, when nine members were present. Various sub-committee meetings were held.

GENERAL.

Due to conditions caused by the War, it has been very difficult for your Committee to obtain much of the data which it desired and presents herewith such as has been obtained.

SUB-COMMITTEE No. 1.

Your Committee at this time does not wish to recommend any important changes in the Manual.

For subjects for consideration of the Ballast Committee in 1919, your Committee recommends the following:

(1) Report on proper depth of ballast of various kinds to insure uniform distribution of loads on the roadbed, conferring with the Special Committee on Stresses in Track and Committee on Roadway.

(2) Report on methods and comparative cost of applying ballast, giving special attention to the organization of the ballast gang.

(3) Study and report on the design of gravel washing plants. Study and report on the design of stone crushing plants.

(4) The use of reinforced concrete slabs or other devices to assist the ballast in distributing the load on soft roadbed.

SUB-COMMITTEE No. 2.

The work assigned to the Sub-Committee is as follows:

"Report on methods and comparative cost of applying ballast, giving special attention to the organization of the ballast gang."

Realizing the condition of stress due to the war under which all railroad men would be working, your Committee has confined itself to the organization of the ballast raising gang, only touching incidently upon cost or work preparatory for and subsequent to the putting in of the ballast.

Cost figures are always interesting and often instructive, provided their scope is precisely defined and clearly understood. If incomplete or indefinite as to the nature and scope of the work they cover, they are misleading and not illuminating, and although they may be true in themselves, they may also be so open to misunderstanding as to have all the effect of serious error.

Partial figures are sometimes of value if accompanied by proper modifying clauses such as:

Pay-roll and local supervision only;
Proper charge for locomotive included, but nothing for cars;
No charge included for use of tools and supplies;
Pit open and track in place;
Engine and train crew included, but no rental or fixed charges on equipment used except rent for locomotive;
Liability insurance omitted.

A circular letter was sent out to the roads represented in the Association to which letter was attached the tentative diagram presented to the Association at its last annual meeting in March, and later printed in the Bulletin. Representatives of the carriers were requested to furnish the Committee with a diagram similar in form showing their typical ballast gang, together with a brief narrative description of the method of using the gang to the best advantage, and any cost figures they might have available.

Some few replies have been received and they have led your Committee to modify the tentative diagram, principally in the way of increasing the number of jackmen, forkers and tampers and restating the flagging requirements.

Notes have been added calling attention to certain matters, among others the fact that upon old track in commercial service, another gang would be required to prepare the way for the ballast raising gang. It is understood, of course, that a finishing gang will follow the ballast gang, after the ballast has been consolidated under traffic, to put the track in proper surface and line, dress the ballast section, dress shoulder, etc.

Some suggestions in the way of detail methods have been made, as follows:

It is helpful to number the men and chalk their numbers on the rail over the particular ties these men are to tamp. The New York Central and the Santa Fe both say it pays in the quality of work obtained.

The Norfolk & Western suggests that the head flagman, whose duties will be light, can tighten bolts and in some instances dig jack holes. The rear flagman can put on rail anchors and tidy up without interfering with his job. This presupposes that the flagging will be done by one of the ballast gang as would be the case on a new line. If regular trainmen are used on an operated line, such work presumably could not be required from them.

Several comment that a tamping spade, heavy and narrow, is better than pick or bar for the first tamping after a raise.

Agreement is pretty general that on an operated track, an advance gang digging out spent ballast, widening shoulder, renewing ties and making general preparation for the spreading of the new ballast, should be handled as a separate unit well in advance of the ballast gang. If track has to be lowered under overhead obstructions, bank widening is required or similar work has to be done. This preliminary work may require a large force and special facilities.

Opinion seems to be divided whether the lifting jacks should be worked in a bunch or in two sets a short distance apart as recommended by the Committee. The Committee would like an expression of opinion of members from the floor on this point.

The Pennsylvania Railroad suggests that on new construction the tampers should be spread out more than is indicated on the diagram.

Suggestions have been made that the head jacks should be heavy No. 6's, which weigh 99 lbs. and would require two men to a jack instead of one. The Committee has accepted the suggestion and modified its diagram accordingly.

There has been heretofore no recommended practice for the guidance of the carriers in connection with the organization of a ballast gang having the endorsement of the Association. An outline has now been presented to the Association for two successive years. It was felt to be of too much importance to be decided by a small committee and the carriers have been twice circularized concerning the matter. In each case, a tentative organization was presented to them as a target for their criticism. Their answers have resulted in the diagram submitted herewith.

Your Committee realizes that circumstances must govern, and any typical organization must be modified to meet local conditions. The diagram is submitted as a guide and as representing good practice under average conditions.

Conclusion.

The diagram as presented should be published in the Manual as representing good practice in the organization of a gang to raise track on new ballast under normal conditions. (See Fig. 1.)

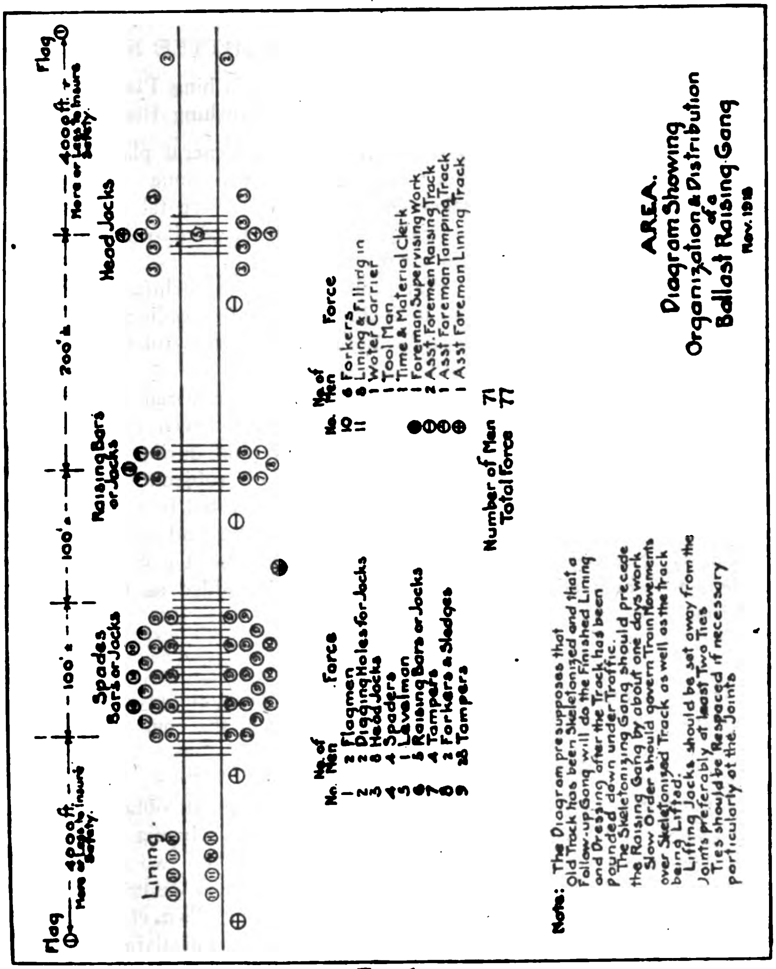

Flag
4000 ft. More or Less to Insure Safety
Lining
Spades Bars or Jacks
100'±
Raising Bars or Jacks
100'±
200'±
Head Jacks
More or Less to Insure Safety 4000 ft.
Flag
No. | No. of Men | Force
1 2 Flagmen
2 2 Digging Holes for Jacks
3 8 Head Jacks
4 4 Spaders
5 1 Levelman
6 5 Raising Bars or Jacks
7 4 Tampers
8 2 Forkers & Sledges
9 28 Tampers
10 6 Forkers
11 8 Lining & Filling in
1 Water Carrier
1 Tool Man
1 Time & Material Clerk
1 Foreman Supervising Work
2 Asst. Foremen Raising Track
1 Asst Foreman Tamping Track
1 Asst Foreman Lining Track
Number of Men 71
Total Force 77
A.R.E.A.
Diagram Showing Organization & Distribution of a Ballast Raising Gang
Nov. 1918
Note: The Diagram presupposes that Old Track has been Skeletonized and that a Follow-up Gang will do the Finished Lining and Dressing after the Track has been pounded down under Traffic.
The Skeletonizing Gang should precede the Raising Gang by about one days work.
Slow Order should govern Train Movements over Skeletonized Track as well as the track being Lifted.
Lifting Jacks should be set away from the Joints preferably at least Two Ties.
Ties should be Respaced if necessary particularly at the Joints.

FIG. 1.

Make reference in the Manual to Bulletin No. 204, dated February 1918, pages 686 to 692, and by similar citation to the information presented in this report and the appendices thereto.

Further study should be given to the organization of an advance skeletonizing and tie renewal gang, and to a follow-up or finishing gang.

SUBJECTS ASSIGNED TO SUB-COMMITTEE No. 3.

1. Study and Report on Design of Gravel Washing Plants.
2. Study and Report on Design of Stone Crushing Plants.

At first it was thought possible to design a general plan and give brief description or specifications for several typical stone crushing and ballast washing plants; but when local conditions were taken into consideration, it was found practically impossible to design such typical plants which would fit all local conditions.

It was, therefore, decided that probably the most helpful method of handling this subject would be to include in the Proceedings a general plan and brief description or specifications of any successful plants which could be obtained.

Therefore, some thirty (30) carriers were circularized with regard to the subject of the design of these plants, and fourteen (14) answers were received; but due to the conditions prevailing during the war, it was impossible to get much information upon this subject.

Five plants have been described, and are illustrated in Figs. 4 to 11, which, together with other plants, both gravel washing and stone crushing, previously described in the Proceedings, the Committee considers the nucleus to which additional similar data may be added as the same is acquired.

Conclusion.

It is recommended that these two subjects be again referred to the Committee for further consideration and report in the coming year.

Method of Cleaning Stone Ballast.

Under this subject the Committee was fortunate in obtaining from W. C. Cushing, Chief Engineer of Maintenance, Pennsylvania Lines West of Pittsburgh, a copy of the descriptive instructions of two methods of cleaning stone ballast, which were issued in 1915 to certain Division Engineers to be followed as a part of the regular ballast cleaning program of that year. Mr. Cushing advises that, due to unsatisfactory labor conditions, conclusions have not yet been reached, and until the supply of labor permits the railroads to return to a more normal condition, it is probable that very little can be learned from a comparative test of these methods.

The instructions in question follow:

Instructions for Cleaning Ballast.

A—Not in connection with tie renewals.

GENERAL.

The space between the ties (cribs) to be cleaned to the bottom of the ties, the space between tracks to be cleaned to 6 in. below the bottom of the ties, and the shoulders outside of the ties to be cleaned down to the top of the sub-ballast, where any. Where there is no sub-ballast, clean to the sub-grade.

Every fifty feet one crib to be cleaned out to a line, on a uniform grade between the bottom of the center ditch and the sub-grade outside the track to form a cross drain from the center ditch.

ORDINARY FORK METHOD.

Under the ordinary method, the ballast to be cleaned in the usual manner by shaking the ballast on forks and throwing the cleaned ballast remaining on the forks back into the track, and the small particles of ballast and dirt which pass between the tines of the forks to be disposed of by throwing it over the bank, or by any other way that may be expedient. When the dirt can be disposed of by throwing over the bank, its cost may be included in with the cleaning. When it is necessary to move the dirt any distance it shall be thrown into piles and the cost of doing so included with the cost of cleaning, but the cost of removing it afterward shall be kept separate and not made a part of the cleaning cost.

Under this method of cleaning it will not be necessary to use a definite number of men in the gang, but it should not be extra large, nor very small. On double track there should be three men in each sub-gang; one on each berme and one in the center. The man in the center to work to the right or left as needed, and those on the sides to work in through the cribs to meet him. The sub-gangs to be started about one hundred feet apart. Thus, with a gang of twelve men they would be spread out over about three hundred feet of track. When starting, the ballast removed will have to be piled up until a space about three feet is cleaned, after which the shaken ballast can be thrown directly back into the track in the three-foot space.

TRENCH-ZEPP METHOD.

For this method three screens are to be used with a force of twelve men and a foreman, distributed as follows: Two men to shovel from each shoulder to their respective screen; two from the center into the center screen, and one man in the center of each track shoveling into the screen most available; one man with a pick working ahead to loosen hardened ballast, and three men, one for each screen, to dress down the ballast on the center and shoulders, form a uniform ballast line and dispose of the dirt. When the dirt can be disposed of by throwing over the bank, its cost may be included in with the cleaning. When it is necessary to move the dirt any distance it shall be thrown into piles and the cost of doing so included with the cost of cleaning, but the cost of removing it afterward shall be kept separate and not made a part of the cleaning cost. When necessary, a water boy in addition to the twelve men can be employed. In operation, the center screen will work ahead of the side screens, and the man attached to this screen will work ahead of the side screens, and the men attached to this screen will clean out the cribs, to about one foot inside of the inside rails of the double track.

Ballast Cleaning Record Form A
(Not in connection with tie renewals)

-------------- Division Date Begun --------191--
-------------- Sub Division Date Ended --------191--
-------------- Section --------- Method

1	2	3	4	5	6	7	8	9
Date	Location	Distance cleaned each day		Cost			Cost of Removing	Remarks Give weather Conditions. Whether ballast is wet or dry. Course or fine and whether section is full or scant.
	M. & P.R.R.	Dbl Trk	No. Men	No. Hours	Rate	Labor Cost	Dirt	

FOR BINDING PURPOSES

Foreman.

FIG. 2.

FOR BINDING PURPOSES

Ballast Cleaning Record
(In Connection with Tie renewals)

Form B

------------ Division Date Begun --------191--

------------ Sub Division Date Finished --------191--

------------ Section --------Method.

1	2	3	4	5	6	7	8	9	10
Date	Location Yd/MP No.	No. of Ties	Distance Covered	Aggregate Ballast Cleaned	Cost of Doing Work				Remarks.
					No. of Men	No. of Hrs.	Rate	Cost	

Note: For ordinary method of renewing ties column 5 need not be filled in. Remarks show weather conditions and any other conditions that may affect the amount of work accomplished.

FIG. 3.

B—In connection with tie renewals:

ORDINARY METHOD.

Under this method such ties as are spotted are to be renewed in the ordinary manner with the ordinary sized force, but a record of the cost to be kept on the attached blank Form B (Fig. 3), for use in comparing this method with the screen method.

SCREEN METHOD.

By this method such ties as are spotted are to be renewed by a force of eight men and a foreman with one screen, and a water boy if thought expedient. The force is to be distributed as follows:

One man picking ballast loose ahead of the gang.

Three men digging the ballast out of the track and throwing it onto the screen.

One man removing the refuse and straightening up the ballast.

Two men removing the spikes, taking out the old tie, putting in the new tie and spiking.

One man following up about 300 to 400 feet in the rear, putting ballast in around the tie and trimming up the track.

All the ballast on the shoulder and in the cribs is to be taken out, but not from the center between tracks (this can be cleaned at another time). Where only one tie is to be renewed clean out the cribs on both sides of the tie. When two ties are to be renewed clean out the crib between the two ties and one crib on the outside of each tie or three cribs. When three ties are to be renewed clean out four cribs, etc.

The work to progress as follows: The first man with a pick will proceed to pick loose the ballast where ties are spotted. The three men cleaning out the ballast from track will follow about twelve feet behind and shovel onto the screen. The one man in charge of the screen will see that the ballast falls onto the track, into pans, or on the outside shoulder, as may be deemed best in each case, for re-use in tamping the new ties. It is left in this shape until the two men who are putting in the ties come along. They will take out the spikes, remove the old tie, put in the new tie and tamp immediately, leveling off enough ballast into the cribs to make the track safe. The man who follows up in the rear is not started until the other force has proceeded far enough to allow as many trains to go over as may be deemed necessary by the foreman to settle the ties and permit of proper retamping. the idea being that the retamping after traffic has gone over it will all be done before the ballast is filled in to its proper section, so that it will not be in the way of tamping.

A record of progress and cost is to be kept on the attached blank, Form B (Fig. 3), and signed by the foreman.

BIBLIOGRAPHY OF BALLAST AND BALLASTING.

As a matter of information the Sub-Committee attaches hereto, as Exhibit "A," a continuation of their bibliography on this subject, which was in last year's report, page 700.

Exhibit "A."

Ballast and Ballasting and Tests of Ballasts.

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REPORT ON THE PROPER DEPTH OF BALLAST OF VARIOUS KINDS TO INSURE UNIFORM DISTRIBUTION OF LOADS ON THE ROADBED, CONFERRING WITH SPECIAL COMMITTEE ON STRESSES IN RAILROAD TRACK AND COMMITTEE ON ROADWAY.

SUB-COMMITTEE No. 4.

Your Committee has been in touch with the Committee on Stresses in Railroad Track, but as that Committee, on account of war conditions, has not been able to put into shape the data which they have on the transmission of the pressure downward through the ballast and in continuing the work to supplement certain parts of it, the Ballast Committee is not in position to recommend any additions or changes under the head of "Proper Depth of Ballast." The Committee, therefore, recommends that this subject be reassigned for the coming year's work.

GENERAL.

Attached hereto as Appendix "F" is a copy of report on use of reinforced concrete slabs at "soft spots" in roadbed, for which the Committee is indebted to J. T. Bowser, of the Queen & Crescent Route, Danville, Ky., also a copy of report dated June 18, 1917, made in the office of the Promotion Bureau of the Universal Portland Cement Co. by Benjamin Wilk.

CONCLUSION.

Your Committee feels that the use of reinforced concrete slabs to assist the ballast in supporting the track on soft spots is an interesting suggestion and should be studied further by the Ballast Committee.

DESCRIPTION OF THE PLANT OF THE DOLESE & SHEPARD STONE CO.

Stone Crushing Plant of the Dolese & Shepard Company, located 15 miles west of Chicago on the Atchison, Topeka & Santa Fe R. R.

The quarry and crushing plant of the Dolese & Shepard Co. is located at Novak, Illinois, on the main line of the Santa Fe Railway, about 15 miles west of the Dearborn Street Station in Chicago.

The quarry and plant cover almost 160 acres of land; the quarry opening being between 75 and 100 acres. The quarry is opened by stripping from six to twelve feet of earth from the rock. The rock is then worked in two levels of about 25 feet depth each.

The stripping of earth is done by steam shovel, after which holes are drilled by well drills, to a depth two of three feet below the bottom of the first level of the quarry. A row of the holes are drilled about 30 feet back from the working face and are charged with heavy explosives, and the entire row of holes fired at one time.

The rock, after being loosened by blasting, is handled by a steam shovel, which loads it into four-wheel dump body cars weighing 15 tons

each and handling 15 tons of rock per load. These cars are driven by electric motors, using a third rail current feed. The third rail is placed in the center of the track, and is cut into sections of varying lengths, and each section is connected by a feed wire which leads from a switchboard in a tower near the crusher plant. The cars are moved without an attendant, by the simple process of switching the current on and off of the various sections from the tower. The motors on the cars also act as a brake, by current reversal.

The rock filled cars are passed over an automatic scale where the weight of each load is ascertained, and from the scale the car is run up an incline to the dump into the first crusher. This first crusher is a No. 18 gyratory crusher, manufactured by the Power and Machine Co.

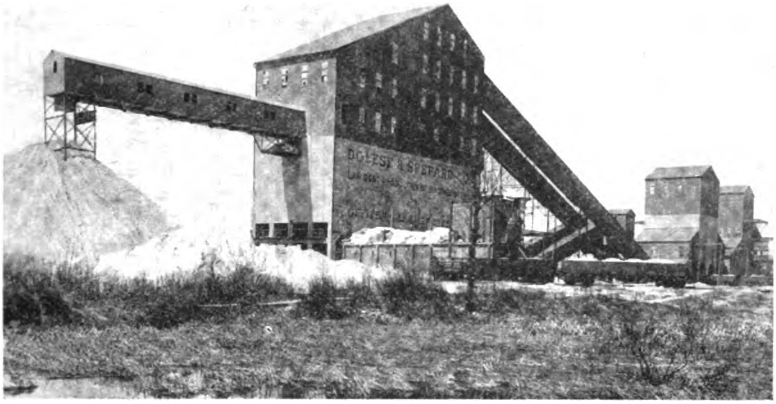


Fig. 4—Plant of Dolese & Shepard Co., Gary, Ind.
Longest Incline, 330 Feet.

The first crusher is of sufficient size to take in 42-inch cubes of rock and crush it to such size as will be handled by a No. 9 crusher of the same type. The 42-inch crusher is driven by a 250 H.P. electric motor, connected by rope transmission to the crusher drive wheel.

The stone, after passing through the 42-inch crusher, drops into a bucket conveyor which carries it upward and into hoppers in the next building, where it is distributed to two No. 9 gyratory crushers, which are also driven by electric motors, but of belt drive, instead of rope drive connection. From the two No. 9 crushers the stone is conveyed to revolving screens with four-inch round openings. All rock which fails to screen out is passed to another bucket conveyor which delivers it to bins which feed into four No. 6 gyratory crushers. From the No. 6 crushers the stone is carried by an endless belt conveyor to the fourth building, where it passes through revolving screens, carry-

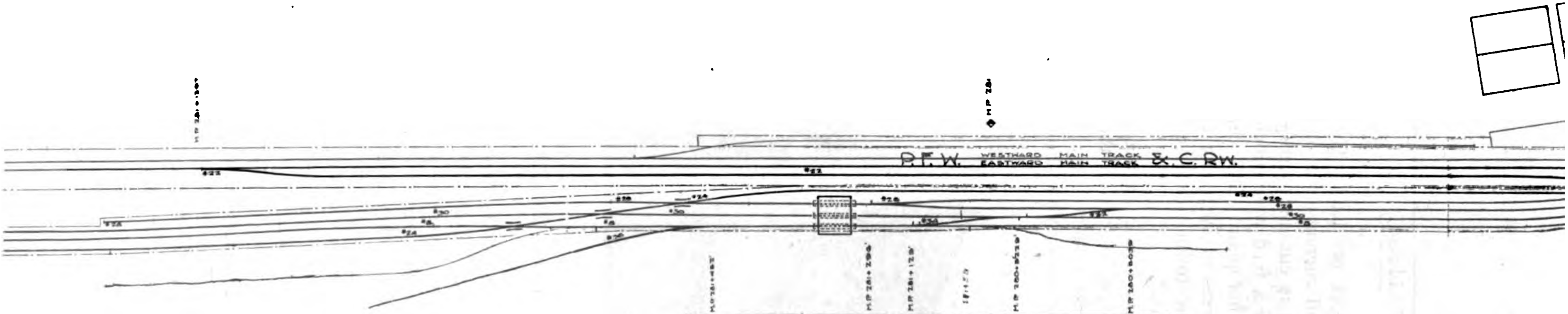


TABLE OF TRACK CHANGES

DESCRIPTION	NUMBER	LENGTH 12-31-14	TAKEN UP	NEW	LENGTH 12-31-15
SOUTH SCREENINGS TRACK.	8	3310	3150	3774	3954.
SOUTH BALLAST TRACK.	28	0	0	3121	3121.
NORTH SCREENINGS TRACK.	30	0	0	3545	3545.
STORAGE TRACK.	22	0	0	2711	2711.
RUNNING TRACK.	24	0	0	3289	3289.
NORTH BALLAST TRACK.	26	0	0	1263	1263.
CROSSOVER, SOUTH BALLAST TRK. TO NORTH SCREENINGS TRK.	32	0	0	178	178.
CROSSOVER NORTH SCREENINGS TRK. TO SOUTH SCREENINGS TRK.	34	0	0	178	178.
CONNECTION TO PIT	36	0	0	90	90

FIG. 5—TRACK CHANGES IN VICINITY OF FRANCE STONE CO., PENNSYLVANIA LINES WEST OF PITTSBURGH, MIDDLEPOINT, OHIO.

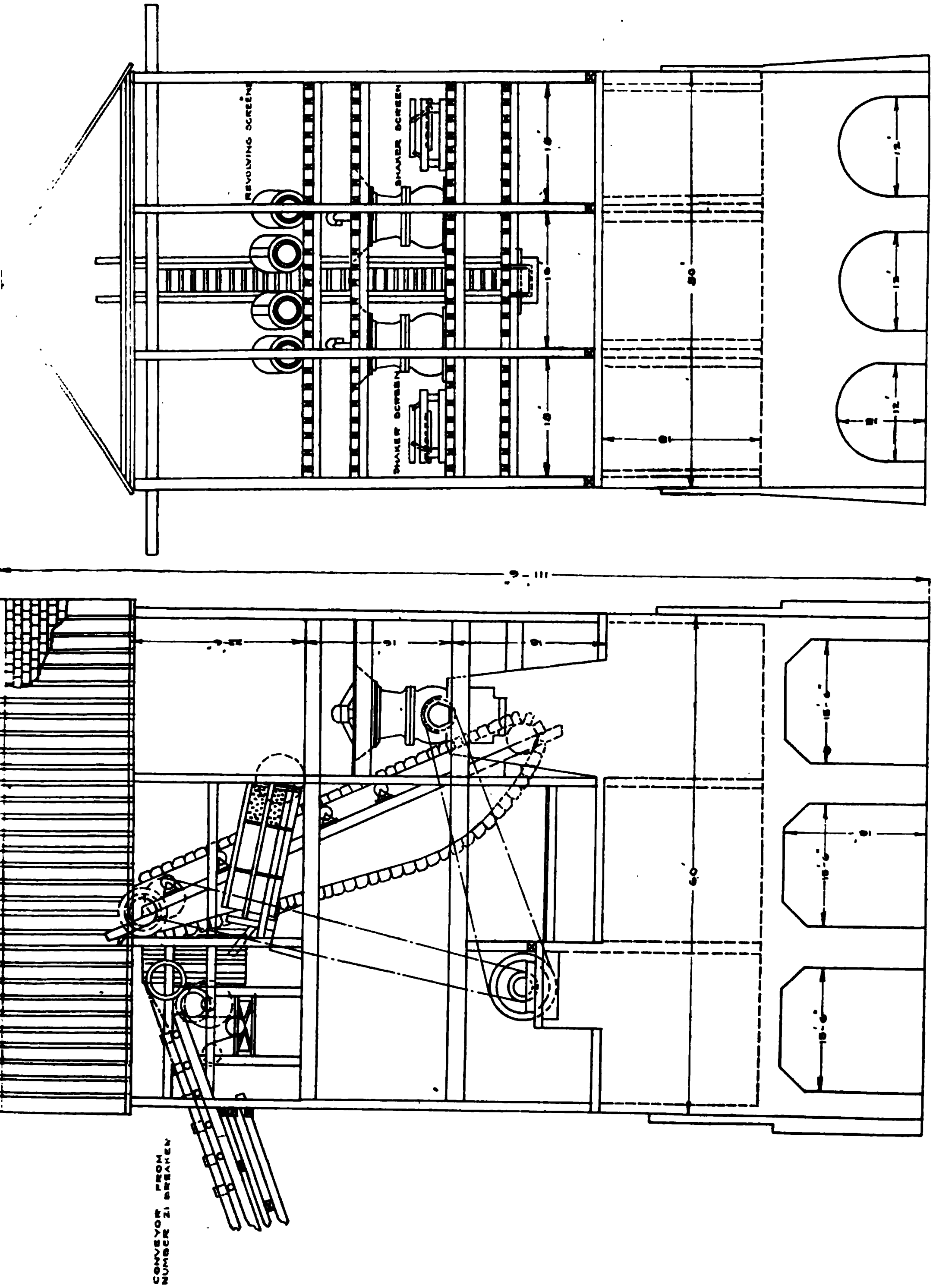


Fig. 6—France Stone Company's Plant, Pennsylvania Lines West of Pittsburgh, Middlepoint, Ohio.

ing openings of ½, 1⅛, 1⅝ and 2-inch round holes. The material passing through the smallest holes of the rotary screens is passed over a shaker sieve screen, which separates the "screenings—F.F." and ¼-inch material, while the rotary screens separate the larger particles into No. 2, No. 3 and larger sizes.

The screens are located in a very high building, so that the various grades of stone are deposited by gravity into immense round bins which are built high enough from the ground to permit standard gondola cars to be passed under them for loading by gravity. The bin gates for holding back the rock when cars are not being loaded are operated by compressed air.

The stone which is removed from the crushed aggregate by the 4-inch screens is deposited in bins for delivery to the steel companies for fluxing material.

A very interesting feature of the plant is that the storage bins, which are about 20 feet in diameter and 80 feet deep and built of concrete, are lined with granite blocks, laid up in cement, and carefully built in, to protect the concrete (of which the bins are made) from wear due to the falling particles of stone. The bin provided for screenings and for ¼-inch aggregate were the only ones not so lined. The receiving and discharge bins at each crusher were also lined with granite blocks.

In the approach to the final screen building there are two large roller crushers located, one for the purpose of further breaking of such material as is carried clear through the revolving screens, and the other a smooth face pair of rolls for the purpose of making screenings or pulverized stone when such material is needed.

The equipment of the plant consists of four steam shovels, one locomotive crane, six well drills, with many air and other small drills, an automatic electric railway with a large number of 4-wheel 15-ton dump cars, a power house with transformers, switches, etc., to receive and distribute the electric current which is purchased from the Public Service Corporation, one No. 18 gyratory crusher, two No. 9 gyratory crushers, four No. 6 gyratory crushers, two roller crushers, endless chain bucket conveyors, belt conveyors, screens and electric motors for driving the various machines.

The plant, of course, includes store house, machine shop, blacksmith shop, etc.

The capacity of this plant with its present equipment is five thousand cubic yards of crushed rock in ten hours.

Stone Crushing Plant Located at Middlepoint, Ohio, on Pennsylvania Lines West, 8 Miles East of Van Wert, Ohio.

Fig. 5 shows the track layout. There are three tracks under the crusher. Empty cars are placed west of the crusher, and the track capacity is 115 cars. The loads are dropped to the east and the loaded tracks have a capacity of 120 cars.

The present plant was erected in 1914 and has a daily capacity of 4,000 tons. Timber construction, except for foundations, is used in the construction of the plant. This, according to the France Company, is preferable, as it is necessary to make frequent changes in stone crushing plants to take care of changed conditions. They state that it is necessary to make additions and alterations every season.

The field operation at Middlepoint quarry is circular in shape, and the stone has been taken out in benches about 15 feet to a bench; and at present the third bench is being removed. The overburden is earth, and averages about 4 feet in depth, and is removed by steam shovels and narrow-gage cars and locomotives and hauled to waste banks.

After the stone is stripped it is drilled by electrically operated churn type well drills, Loomis Machinery Company Clipper drills being used. Special care is exercised in spacing and depths of drill holes, as depths of working face strata of stone and strength of explosive is taken into account, so that in the blasting operation the stone will be shattered but will not be broken down from its original position in the bank. Dynamite is the explosive used.

Two Marion Model 91 steam shovels are used to load the stone from the bank into the side dump 36-inch gage cars, which are handled by dinkey locomotives to the initial crusher. This crusher is a No. 21 Gates, manufactured by the Allis-Chalmers Company and weighs 64 tons, and is located at the quarry floor level, at the foot of a belt conveyor, which conveys the stone after it has passed through the No. 21 breaker to the crushing plant or mill proper.

This conveyor, above mentioned, discharges into a bin at the top of the mill from which the stone is distributed into two of a battery of four revolving screens, the sized stone or finished product is removed by these screens, and the oversized stone or rejections pass out the end of these two screens in two No. 9 McCully breakers, which are termed rebreakers. From the rebreakers this stone passes into a bucket elevator and is elevated again to the top of the mill, where it passes into the other two of the battery of four revolving screens, and the oversized stone or rejections again go to the rebreakers, and so on until it is properly sized and passes through the revolving screens. After the stone passes through the revolving screens, the smaller sized stone passes onto two shaker screens on the next floor below, where it is again sized and cleaned and is in turn passed into the proper bin.

The bins are located immediately over three loading tracks, three (3) bins over each track, and each bin has a capacity of 150 tons, giving a total bin capacity for the plant of approximately 1,350 tons.

At this quarry everything is electrically driven, with the exception of locomotives and steam shovels, there being 16 motors ranging in size from ½ H.P. to 300 H.P., required for complete operation of crushing plant and field.

Stone Crushing Plant Located at Pembroke, Va., on Norfolk & Western Railroad.

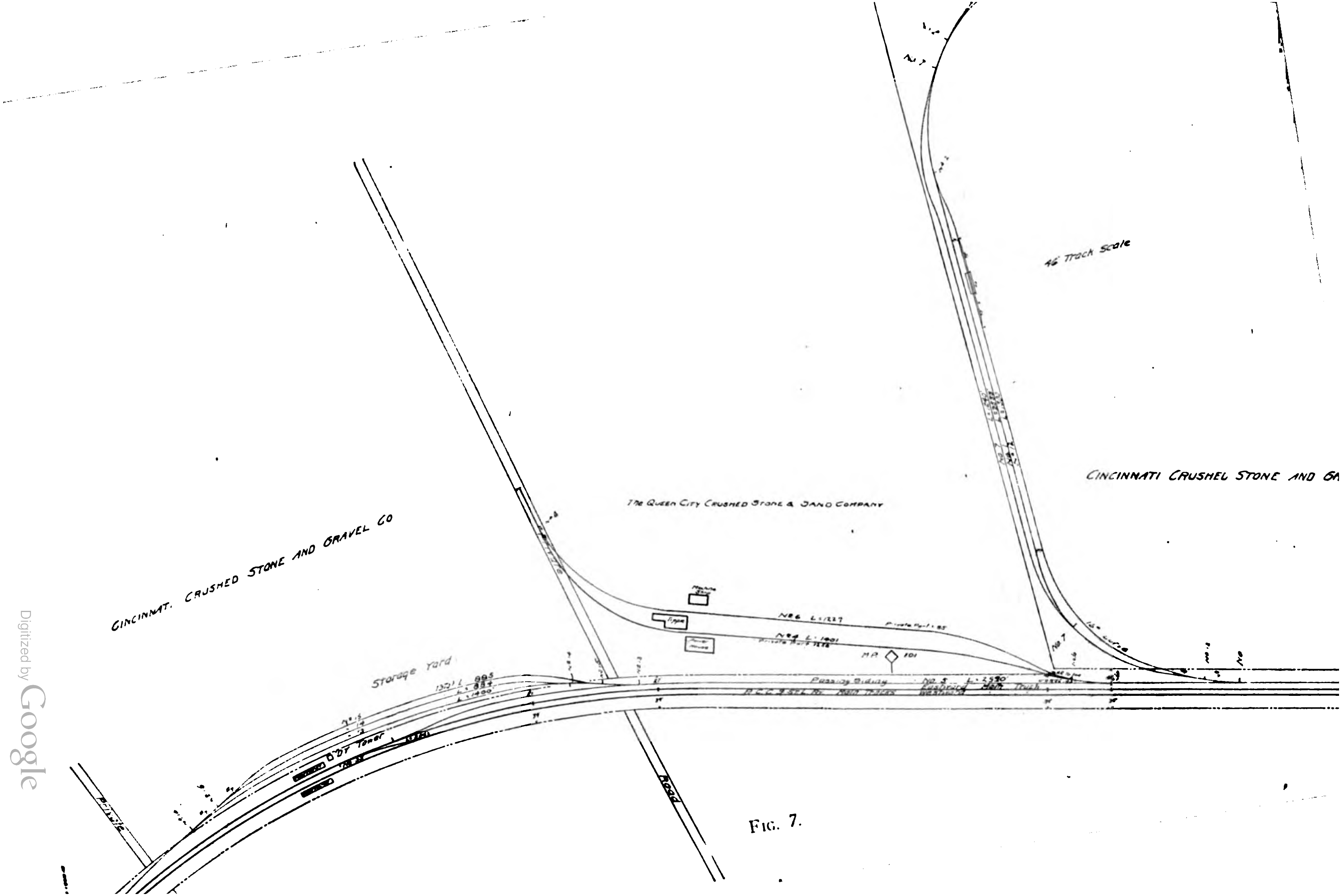
The plant is located about one-half mile from the quarry. The quarry was origially started up a ravine widening, which had very precipitous limestone bluffs on each side. We opened up this quarry with a face about 1,000 feet long on each side of the ravine and have been operating there for six seasons; and at this time the faces of the two bluffs are about 600 feet apart, and the bluffs vary in height from one hundred and fifty to two hundred feet high. We work this quarry in benches, using Ingersoll-Rand drills largely for drilling, drilling the holes in the benches about twenty feet deep. When this shot on the bench is put off, we immediately set up the tripod drills again, start them, and then the jackhammer drill men start on the bottom and plug-hole all the rocks that are too large to go through a 2½-yard dipper. We try to use just enough men on the jackhammers to get this rock drilled and broken up by the time another line of twenty-foot holes have been put down in the bench and loaded; then this shot is put off and the same process is followed again until we get to the bottom of the bluff, by which time we have anywhere from fifty to one hundred thousand yards of rock shot down.

This quarry having two faces, we have the shovel at work on the opposite side from where the drills are working, and when all this stone has been cleaned up on one side the shovel is transferred to the opposite side (which can be done by having a permanent track across this quarry) in about two hours. Then the drilling operation begins on the side that the shovel comes from and the shovel goes to work upon the side that the drilling and shooting has been done on. In this way the operation of drilling and shooting never interferes with the shovels' loading, and, therefore, have no lost time.

We have some four to ten feet of overburden on the top of this quarry which is thrown over the bluff in the months of January and February, and then the railroad company puts their standard gage equipment in and we load these strippings on them and it is hauled out and used in widening banks along the main line or for any purposes the railroad company may see fit to use it.

The plant consists of the following equipment:

1 No. 12 Gates breaker fitted with steel spider, special open-harth oil tempered shaft, manganese steel mantle and sectional manganese steel concaves.
1 60 in. x 12 ft. Gates iron frame revolving screen with manganese steel protecting liners made extra heavy throughout.
1 Elevator complete, 36 in. x 16 in. by 13 in. buckets, 58 ft. centers including wood frame and bucket belt.
2 No. 6 "K" Gates breakers fitted with manganese steel mantle and sectional manganese steel concaves.
2 48 in. x 16 ft. Gates iron revolving screens with manganese steel protecting liners, made extra heavy throughout.
1 12 ton overhead trolley for No. 12 crusher.



46' Track Scale
Cincinnati Crushel Stone and Gr
The Queen City Crushed Stone & Sand Company
Cincinnat. Crushed Stone and Gravel Co
Storage Yard
Passing Siding
Main Track
Road
Private

Fig. 7.

1 6 ton Yale & Towne triplex chain block.
1 12 ton Yale & Towne triplex chain block.
1 30 in. troughing conveyor belts, 5 ply, 50 ft. centers.
1 Elevator complete, 24 in. x 13½ in. x 10 in. buckets, 59 ft. centers, including wood frame and bucket belt.
1 18 in. x 42 in. Allis Chalmers horizontal Corliss engine, heavy duty type.
3 200 H.P. horizontal return tubular boilers.
1 7 in. x 4½ in. x 10 in. duplex boiler feed pumps, 550 H. P.
1 500 H.P. open type feed water heater.
All necessary transmission machinery.
1 Model 70 Marion steam shovel.
3 11 in. x 16 in. Vulcan locomotives.
1 20 in. x 22¼ in. x 14¼ in. x 21 in. Class AA2 Ingersoll-Rand Air Compressor.
2 Water tanks.
2 Water pumps.
Pipe.
1 16x18¼x12¼x16 Class AA2 compressor.
10 E-24 Ingersoll-Rand drills.
4 F. L. 12 Sullivan drills.
4 Ingersoll-Rand jackhammer drills.
Extra tripods and weights.
30 Special 4-yd. cars (K&J).

We have in connection with this equipment an Ingersoll-Rand drill sharpener which does all hte drill sharpening for the entire quarry.

There is only one team used in connection with this entire plant, and this is used for hauling supplies around the camp.

Gravel Washing Plant Located at Miamiville, Ohio, on Pennsylvania Lines West, 18 Miles Northeast of Cincinnati, Ohio.

The plant at Miamiville, Ohio, is owned by the Cincinnati Crushed Stone & Gravel Company, and is an efficiently operated plant. The product is a very good quality of washed and screened gravel. (Fig. 7.)

The gravel is loaded by steam shovels, hauled to the foot of a cable-operated incline by dinkey locomotives, raised to the top of the incline by cable, and dumped automatically into bins. The material is washed to remove the mud and very fine material, and thereafter screened to separate it into various sizes. Boulders are crushed and hauled as at stone crusher plants. Railroad cars are operated by gravity at the plant, after having been set on the empty tracks above the tipple.

Gravel Washing Plant Located at Macksville, Ind., on Pennsylvania Lines West.

The plant at Macksville, Ind., was constructed about two and one-half years ago, and was designed by J. C. Buckbee Co., Chicago. The machinery was furnished by the Stephans-Adamson Company, and the plant was erected by railroad forces.

The raw gravel in their pit at this point is dirty and consists of a large proportion of fine sand—about 25 cars of washed gravel being obtained from 40 cars of raw gravel after passing through the machine.

While the machine, as designed, does the work for which it was built, yet the hopper arrangement used in dropping raw gravel from cars to the movable belt is not large enough to furnish gravel to the full capacity of the belt. The only way this could be done would be by means of a double track over the hopper.

The plans show settling boxes to be used for taking out the sand, but on account of the large proportion of sand in this particular gravel, they have not proved a complete success, and the last separation of sand is made by means of a ⅛ in. screen.

CONCRETE ELIMINATES SOFT SPOTS IN RAILWAY ROADBEDS.

Slabs Easily Placed and More Effective Than One-Man Stone for Stretches Where Tile Drains Are Not Feasible.

By J. T. Bowser,

Maintenance of Way Department, Southern Railway, Danville, Ky.

Maintenance of way officials on many roads are familiar with the soft spots which develop, due to inadequate drainage, in cuts in roadbed where the material consists of certain kinds of clay. Many of these are scarcely more than a rail or two in length and are usually due to lack of proper drainage. In nearly all cases they can be economically remedied by the use of drain tile, but in some cases where there is only a small place in a long cut, the expense of carrying the tile drain to some point where the water can be disposed of is so great that other means must be found to remedy the trouble. The practice of many section foremen to remedy such places by using one-man stone under the ballast bed after removing the material in the roadbed to a small depth is, at least, only a temporary remedy, and the place will continue to give trouble each year in the early spring. An improvement of this practice by using concrete has been found to eliminate this trouble entirely, and in cases where this method has been used the improvement promises to be permanent.

The method consists in the casting in place of a concrete slab under a part or all of the track where the soft place is located. This at first sounds expensive. No forms are required, however, reinforcement is not absolutely necessary, the mixture is comparatively lean, and work can be handled by the section forces. Consequently, the expense is not out of proportion to the advantage gained.

How to Place the Slab.

The construction of the slab can be handled quite as economically as follows:

The width of the roadbed permitting, the track is lined away about 1 foot from the side on which the spot gives the trouble. (As a rule these spots affect one side only.) The ballast is then removed from the space in which the slab is to be placed, back about underneath the near rail. An excavation is then made in the roadbed to a depth of from 2 to 3 feet, and concrete is placed in the excavation up to, or a few inches below, the level of the roadbed. The inside edge of this concrete is left quite rough to insure a good bond with the balance of the slab, which is placed later.

When this section has set the track is lined back to normal and the ties are blocked up on the completed section of the slab. Alternate ties are then removed to facilitate the excavation under the slab. This excavation is usually made back to or slightly beyond the center of the track,

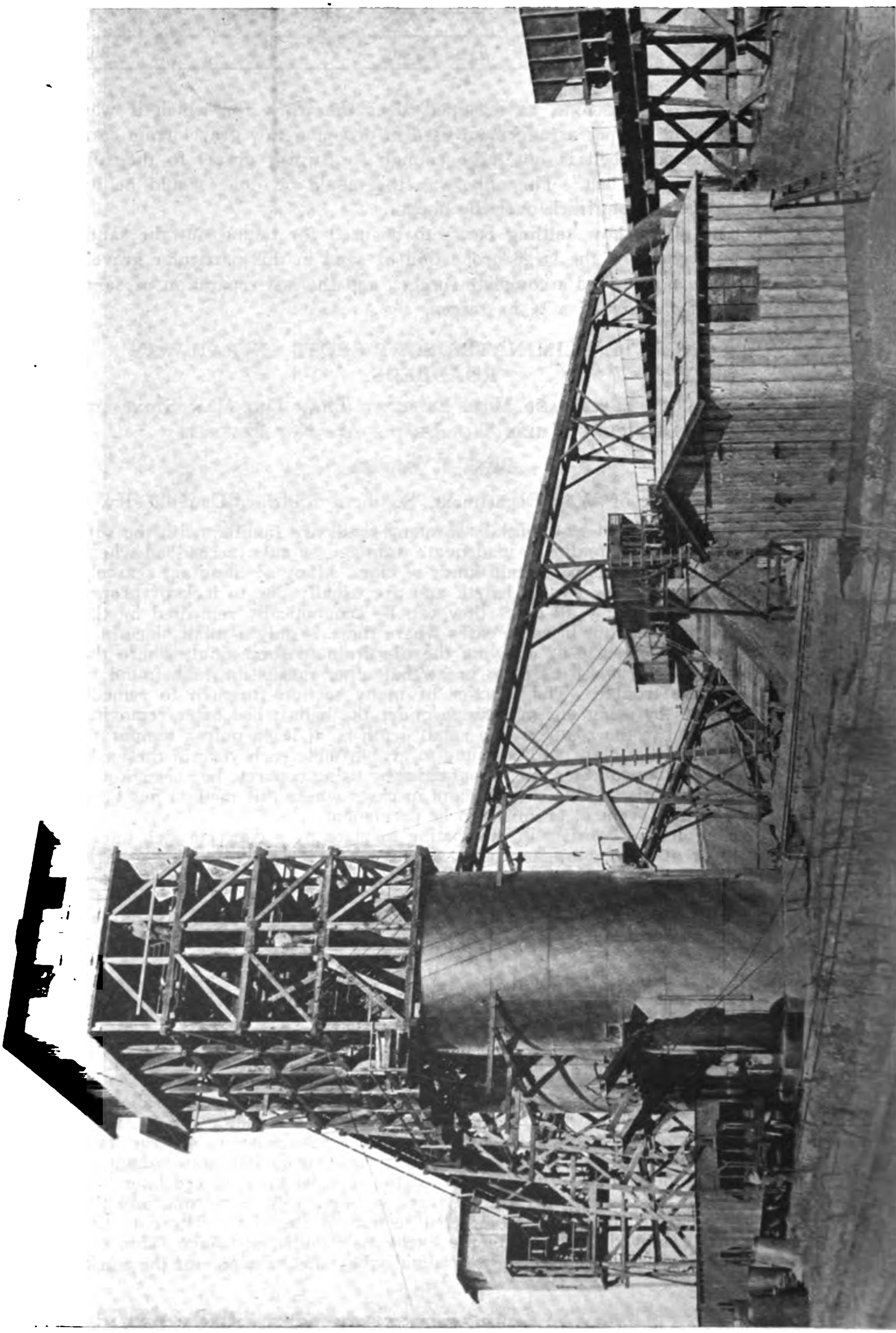


FIG. 8.—GRAVEL WASHING PLANT, PENNSYLVANIA LINES, MACKSVILLE, IND.
Designed by J. C. Buckbee Co., Chicago.

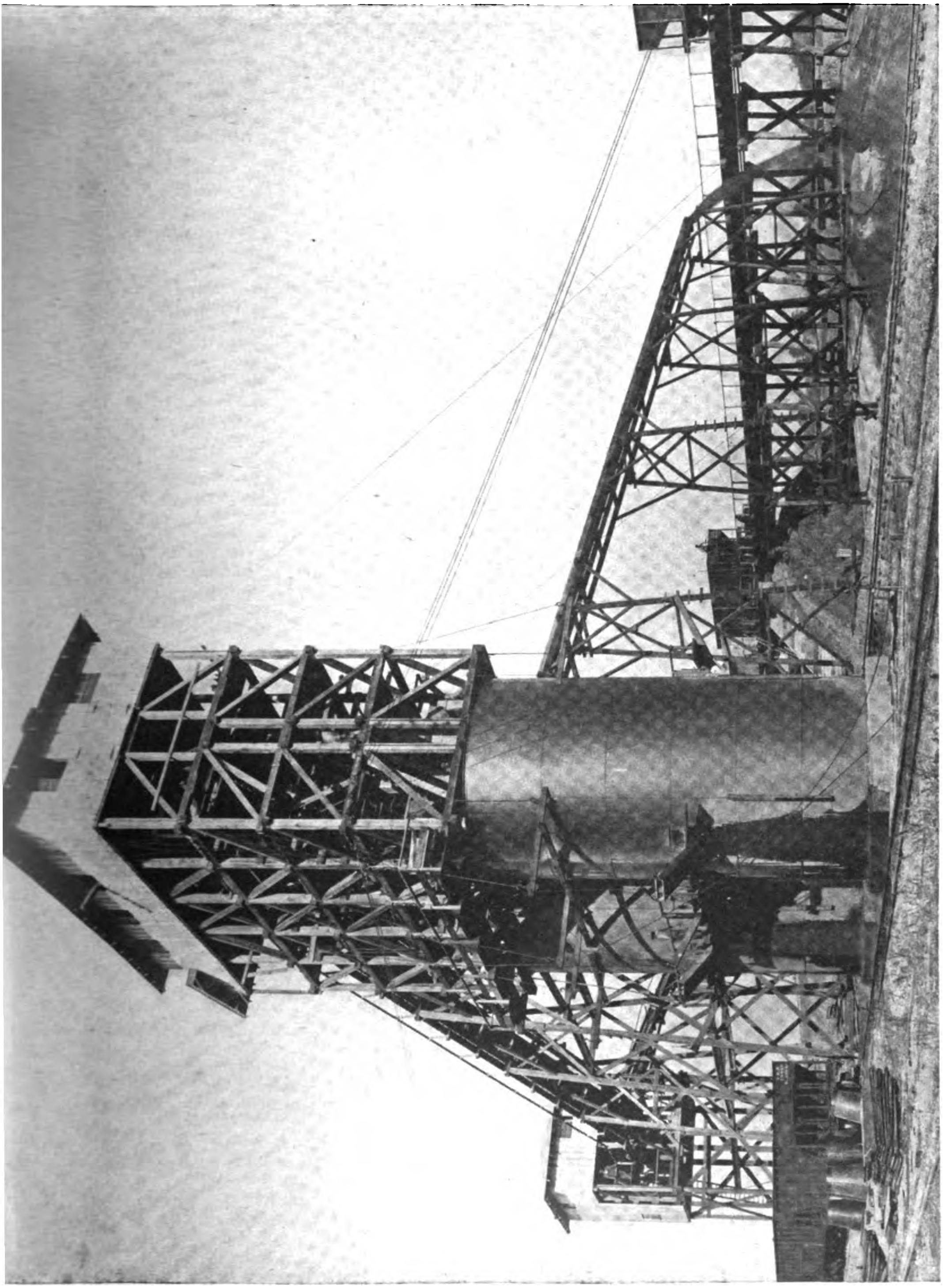


FIG. 9.—GRAVEL WASHING PLANT, PENNSYLVANIA LINES, MACKSVILLE, IND.
Designed by J. C. Buckbee Co., Chicago.

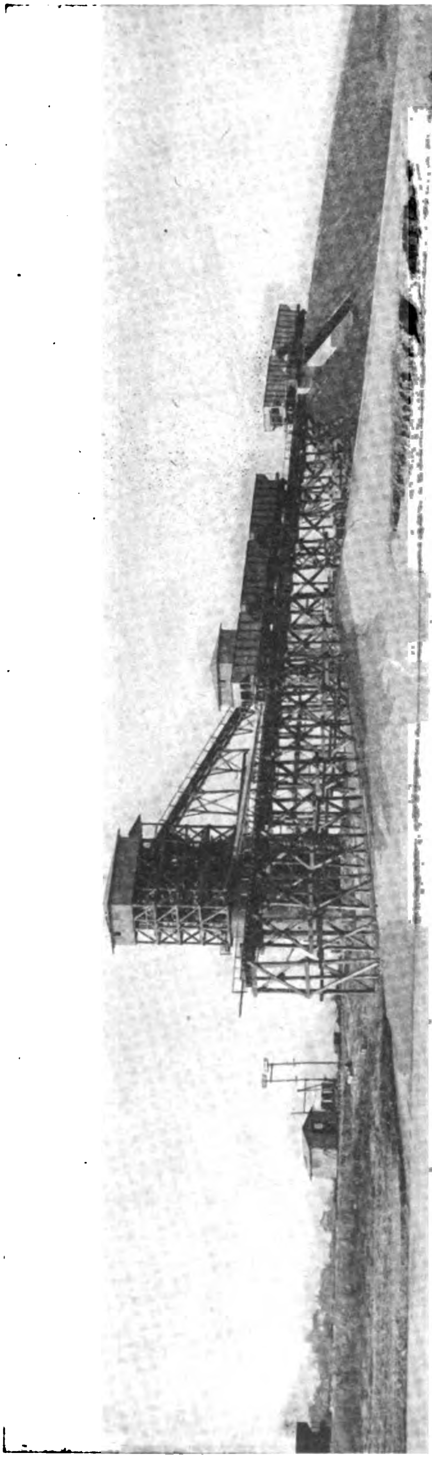


FIG. 10.—GRAVEL WASHING PLANT, PENNSYLVANIA LINES, MACKSVILLE, IND.
Designed by J. C. Buckbee Co., Chicago.

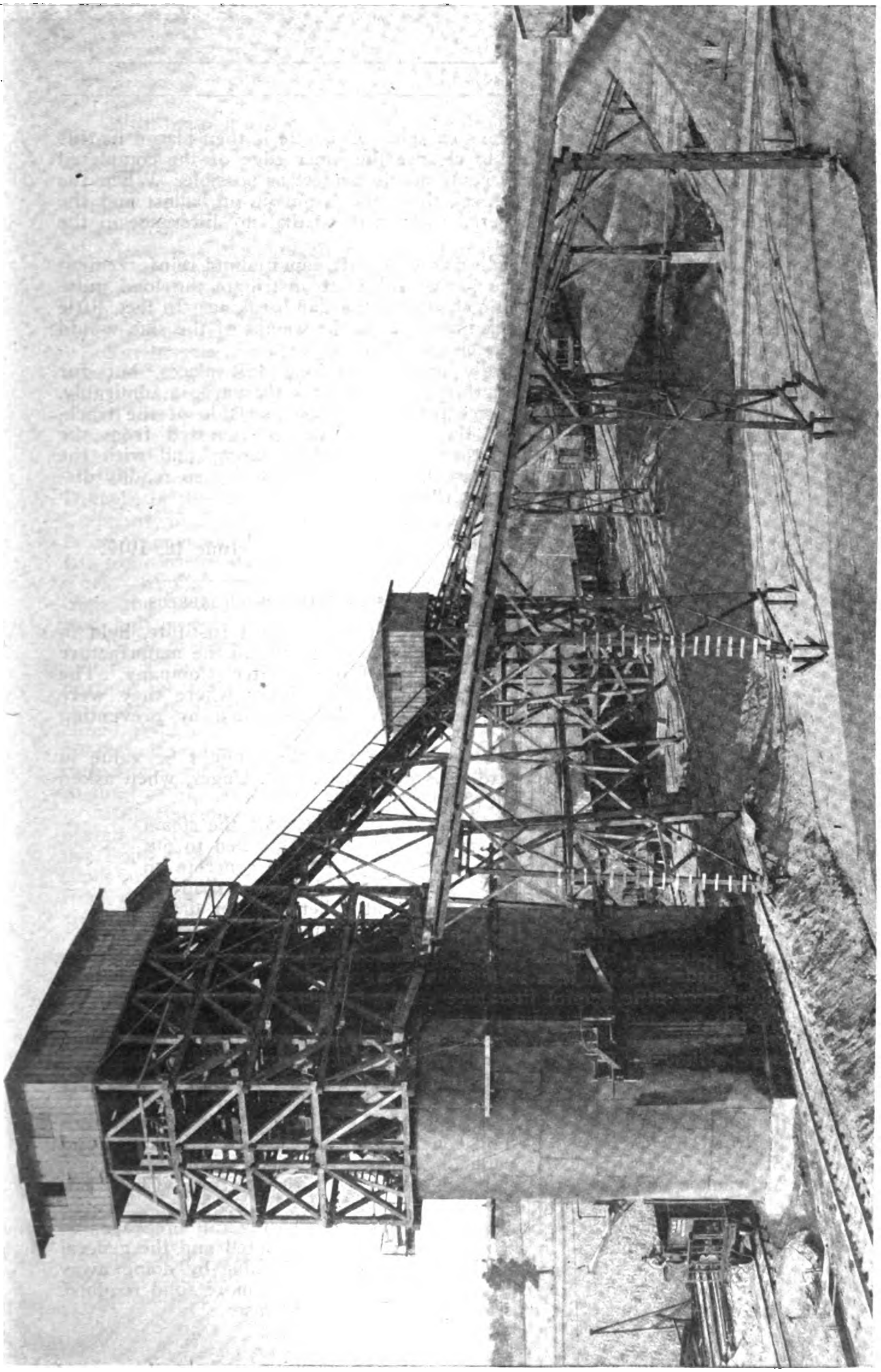


FIG. 11.—GRAVEL WASHING PLANT, PENNSYLVANIA LINES, MACKSVILLE, IND.
Designed by J. C. Buckbee Co., Chicago.

depending on the nature of the soft spot. Concrete is then placed in this excavation, care being taken to cleanse the inner edge of the completed section, so that the bond may be as nearly perfect as possible. When the second section of the slab has set, the track is put up on ballast and the outer edge of the slab is covered with earth so that no difference in the roadbed is shown.

If the material in the roadbed is very soft, longitudinal reinforcement may be necessary, but as the ballast seems to distribute the load quite evenly, there appears to be little chance of the slab breaking. In fact, little trouble would result from such breakage, as the weight of the slab would probably hold it practically in place.

This construction is hardly adapted to long soft places, but for pockets of a rail or two in length it seems to serve the purpose admirably. While these pockets usually give trouble only on one side of the track, where both sides are affected the operation can be repeated from the opposite side. The ballast is thus given a solid bearing, and with the loads distributed over a large area the soft material is not so readily displaced and there is little or no settlement.

June 18, 1917.

Mr. Wm. M. Kinney:

Investigation of Concrete Slabs in Railroad Roadbeds.

During a meeting of the American Iron and Steel Institute, held in New York last May, one of our officials heard a talk on the manufacture of rails given by Dr. J. S. Unger, of the Carnegie Steel Company. The point was made that rails did not break on bridges where they were uniformly supported and that breaks can be prevented by preventing vibration.

This statement gave birth to an idea that there might be value in laying railroad ties on concrete slabs or girders. Dr. Unger, when asked for his opinion, wrote as follows:

> "As wheel loads are constantly increasing, the steam railroad of the future will probably be compelled to put down a continuous reinforced heavy slab of concrete on the subgrade. This slab would cover the entire roadway and possibly include the ditches at either side for drainage. On this slab the ties and rails would be laid."

Encouraged by these words it was suggested that this matter be given study. As the idea seemed to be an absolutely new one we at first found very little helpful literature on the subject. Interviewing railroad officials was the next point of attack and though our first efforts were unproductive of results we found that the most prominent railroad men were willing to discuss the proposition. Among the railroad officials in Chicago who went into details and gave us much encouragement were A. S. Baldwin, Chief Engineer of the Illinois Central Railroad; W. J. Towne, Assistant General Manager of the Chicago and Northwestern Railroad; A. G. Holt, Assistant Chief Engineer, Chicago, Milwaukee and St. Paul Railroad; W. H. Penfield, Assistant to Vice-President, Chicago, Milwaukee and St. Paul Railroad, and W. L. Breckinridge, Chief Engineer, Burlington Railroad.

Almost from the beginning the idea of eliminating rail breakages as the reason for putting in a concrete slab was discounted and the general conclusion was that a concrete slab would be of value by doing away with much of the drainage troubles and by making a more solid roadbed, but that it might not be feasible because of the expense.

With the opinions of these men as a basis, we sent out a general letter to the Chief Engineers of every railroad in the United States having a mileage of over 2,000 miles, asking for their ideas regarding concrete slabs in railroad roadbeds. Half of these letters were answered and a number of replies went into details as to how such concrete slabs should be constructed.

A number of engineers did not think the idea at all worth considering, especially because of the expense, but the idea proved interesting to a majority of the most prominent railroad engineers in the country, who gave their suggestions and also referred to a few experiments that had already been made.

Further correspondence with these men brought out additional features, but most of the investigation centered around two distinct ideas, which were given much attention: first, that a concrete slab be used in which wooden blocks are imbedded to which the rail is attached, and second, a thin concrete slab which would act as a division between the ballast and the earth roadbed.

The first idea has been used in the Michigan Central tunnel near Detroit, in the subway at Philadelphia by the Philadelphia Rapid Transit Company, by the Delaware, Lackawanna and Western Railroad Company in its tunnel at Hoboken, New Jersey, and the Pennsylvania Railroad, for some of its station tracks and a portion of its tunnel tracks at New York. Similar construction will be used in the new Union Station, Chicago, the track design of which we have been in touch with during the past half year.

As at present worked out for the Union Station terminal yards, there will be a concrete slab 10 inches thick extending between the walls supporting the platforms. This slab will be reinforced longitudinally and transversely by ¾-inch square rods placed near top and bottom. No inclined rods will be used. Above this "live" concrete slab there will be another layer of concrete 11½ inches thick, in which creosoted ties 7 inches by 9 inches by 2 feet 6 inches are imbedded. The rails are fastened to the ties by screw spikes passing through tie plates.

Experimental concrete slabs in which short ties are imbedded were placed by the Northern Pacific Railroad on some new construction on the Point Defiance line just out of Tacoma, Washington, in 1914. Three types of slabs of varying cross-sections were used, but the officials of the road do not believe sufficient time has elapsed to make records conclusive.

That a concrete slab somewhat similar to those just described would be valuable in a railroad roadbed was first suggested by J. W. Schaub, a well-known Consulting Bridge Engineer of Chicago, who died about six years ago. In an article in Engineering News for January 5, 1899, on "A Design for a Permanent Track for Steam Railroads," he showed figures to prove the economy of such construction. Mr. Schaub advocated his proposition to the railroad officials in Chicago and in the November 2, 1905, issue of Engineering News published a paper on "Proposed Concrete Floor for Railway Bridges and Tracks." His new design did away with all ballast and cross-ties and the track rails rested on a longitudinal timber bolted to the concrete floor. Nothing definite seems to have come out of Mr. Schaub's ideas.

A thin slab to act merely as a division between the ballast and earth was first suggested to us during our present investigation by C. A. Paquette, Chief Engineer of the "Big Four" Railroad. He had been considering such a slab for a long time, but hesitated to give it publicity, because it seemed so radical. His reasons for advocating such a slab are as follows:

"The concrete slab presents one advantage—drainage, but in that one item is covered by far the most important element—track maintenance. Under ordinary construction the ballast is pounded into an unseasoned roadway and the first wet weather results in pumping the mud up to the ties. The ballast becomes foul within a very short time and fails in its performance of the function of drainage. At the very least the first application of ballast and the first renewal thereof go eventually to the making of nothing more than the roadbed for succeeding ballast applications. In recent investigations we have found cases where the ballast was 5 and 6 feet deep on account of rapid renewals, but all of the ballast was more or less mixed with the earth which had worked up its way through successive seasons. Track and roadway construction, so designed that an effective division can be maintained between the ballast and the roadway, would go far toward insuring good track conditions with much less expense than is involved in the present practice because the ballast, the function of which is to keep the water away from the track superstructure, will be kept clean."

Somewhat thicker slabs were used by the Long Island Railroad on some special work at Jamaica, New York, during the winter of 1912 and 1913 on what is known as the Jamaica Terminal Improvement. These slabs are 8 inches thick and there is 9 inches of stone ballast between them and the bottom of the ties. J. A. McCrea, General Manager of the railroad, in commenting on this construction, states:

"These slabs are placed under 49 crossings, switches and slips of 100-pound rail and the total area was over 73,000 square feet. The embankment was composed of sand, and averaged 20 feet high; a portion of the slab was placed without allowing time for the embankment to settle. The traffic has been extremely heavy from the day it was put in service, May, 1913, running as high as 1,300 train movements per day. The switches are interlocked, electro-pneumatic system, and the Signal Department states that there has been practically no movement of the rail that has caused them any trouble with the locking devices, and they attribute it to the presence of the slab underneath. The Maintenance Department states that since the track was put in proper shape there has been practically no maintenance after 3½ years' service. This is particularly noticeable in the frogs, which do not 'rack' or loosen the bolts, and none have been replaced through this territory to date."

Concrete slabs are now used by several railroads under crossing frogs. As used by the Burlington Railroad, the slab is 18 inches thick, reinforced, and extends 6 inches beyond the ends of the crossing frog ties. The top of the slab is either 4 inches or 6 inches below the bottom of the ties. Regular ballast is used. Just below the slab there are two feet of crushed rock, while drain tile at the base of this layer and leading to a nearby outlet takes care of the drainage.

In determining the value of a concrete slab it is well to call attention to the opinion of James E. Howard, Engineer-Physicist of the Division of Safety of the Interstate Commerce Commission, who was so interested in our investigation that he made a personal call on us in company with H .W. Belnap, chief of that division. Mr. Howard believes that concrete slabs will be beneficial to new as well as to old roadbeds, and feels that the present roadbeds can be considerably improved. He has had much experience in investigating rail fractures and believes that many of these fractures should be blamed, not to the rails, as is the general practice

among the railroads, but to the condition of the roadbed. Unevenness in roadbed creates large stresses in rails as high-speed trains pound along the track. Stresses now developed are equivalent to those obtained when a span length, equal to a spacing of three ties, is figured. With a perfectly even roadbed the stresses would be comparatively low, as the span length would be considerably less. Rail breakages would be fewer and heavier loads could be carried with the present weight of rail; in fact, a rigid roadbed is desirable, as it would eliminate all vertical motion and give greater tractive power in the horizontal direction. Mr. Howard emphasizes this idea of additional tractive power due to an even roadbed. He feels that the railroad companies have not as yet taken this idea into consideration.

Synopses of the opinions and ideas that we have received from railroad officials, by correspondence and interviews, are herewith attached.

Yours very truly,

(Signed) BENJ. WILK.

SYNOPSES OF CORRESPONDENCE AND INTERVIEWS WITH RAILROAD OFFICIALS REGARDING CONCRETE SLABS IN RAILROAD ROADBEDS.

R. N. Begien, Chief Engineer (Now Federal Manager Western Lines), Baltimore & Ohio System, Cincinnati, Ohio.

Concrete will have quite a place in future development toward more economical roadbeds. Feels it is only a matter of a few years before present type of roadbed construction will have to be changed, particularly because wooden ties will have to be replaced by some other material.

A. S. Baldwin, Chief Engineer Corporation, Illinois Central Railroad Company, Chicago.

Much merit in concrete slabs. Use precast slabs hardened for a considerable length of time. Traffic interrupted for only a short time. If designed, after considerable experimentation, such slabs would decrease cost of maintenance and take care of vexing problem of drainage. This idea of special advantage to heavy traffic roads which have high maintenance charges. Refers to early idea of Mr. Schaub.

J. A. McCrea, General Manager, Long Island Railroad Company, New York City.

Slabs should be in lengths of 20 feet, about 10 feet wide, 8 inches thick, of 1:3:6 concrete unreinforced, 6 inches to 8 inches below tie. They will eliminate inadequate drainage, will increase bearing surface on natural ground over three times usual method. Experimental slabs at Jamaica, New York, very satisfactory. (See quotation in complete report.)

C. A. Paquette, Chief Engineer, "Big Four" Railroad, Cincinnati, Ohio.

Advocates four-inch to six-inch slab as division between ballast and earth. This would help drainage. Does not favor concrete slab with rail directly attached. Has used slabs under crossing frogs where maintenance has been difficult matter.

W. C. Cushing, Chief Engineer, Maintenance of Way, Pennsylvania Lines, Pittsburgh, Pennsylvania.

Concrete slabs have been considered by this company for some time. A section was almost built during some construction work four or five years ago. Uncertainty of value due to settlement of embankments and to large cost. Slab was to be under ballast. He has found concrete slabs under railroad crossings very valuable for keeping up crossing frogs.

James E. Howard, Engineer-Physicist, Division of Safety, Interstate Commerce Commission, Washington, D. C.

Believes suitable slab can be devised which will be useful to railroads. Emphasizes need for careful experimentation.

H. E. Stevens, Chief Engineer, Northern Pacific Railroad Company, St. Paul, Minnesota.

Has experimented with slabs in which wood blocks are embedded to which rails are attached. No conclusions yet formed. Does not favor thin slab. Very much interested in our investigation.

A. O. Cunningham, Chief Engineer, Wabash Railroad, St. Louis, Missouri.

Very much in favor of slab under ballast. Track maintenance important, inadequate drainage eliminated. Slab 12 inches under ballast, 6 to 8 inches thick, reinforced. Slope from center to sides. High cost of continuous slab makes it almost impracticable. No value in a slab with ties directly attached. Under crossing frogs slabs have been found of great advantage. He suggested this use several years ago.

W. L. Breckinridge, Chief Engineer, Burlington Railroad, Chicago.

Crossing frog slabs in use for over a year, but no report on them available. He believes they have value. Under high-speed traffic, concrete slab with directly attached tie and rail would be shattered. If slabs now in are successful, will develop their use under ladder tracks and in switch yards. Continuous concrete slab would be very expensive.

J. E. Willoughby, Chief Engineer, Atlantic Coast Line Railway, Wilmington, North Carolina.

If a concrete slab be constructed it should find support in the surface of the earth underneath. If the subgrade be sand, gravel or rock the slab can be constructed directly thereon. If the subgrade be not self-draining material, the slab must necessarily be supported on piles or piers. The ties should rest directly on the slab and be imbedded therein.

Geo. H. Webb, Chief Engineer, Michigan Central Railroad, Detroit, Michigan.

Has often considered concrete slab between subgrade and ballast—might be called "waterproofing." Cost too great. Is considering concrete tie. Experimental tracks put in nine years ago, which were studied to learn effect of traffic on ties embedded in concrete prior to construction of track system in Detroit River Tunnel, are in very good condition.

G. J. Ray, Chief Engineer, Delaware, Lackawanna & Western Railroad, Hoboken, New Jersey.

Question has been seriously considered for past ten years. Where subgrade is absolutely permanent, as in tunnel work and terminals, plan can be used. Does not agree regarding breakages of rails on bridges. Best rails often break on most solid bridge structures.

Samuel T. Wagner, Chief Engineer Corporation, Philadelphia & Reading Railway Company, Philadelphia, Pennsylvania.

Interested in our proposition.

A. H. Hogeland, Chief Engineer, Great Northern Railway, St. Paul, Minnesota.

Believes thin slab between ballast and earth only feasible idea possible. Will give very good drainage. Company has not given any consideration to this subject as traffic is lighter than on eastern roads.

A. G. Holt, Assistant Chief Engineer, Chicago, Milwaukee & St. Paul Railroad, Chicago, Illinois.

Favorably impressed with idea. Drainage eliminated, an important point. Settlement of embankments must be given much attention. Improving drainage would help stabilize embankments. Figure cost of slab against saving in maintenance to prove its value.

H. C. Lothholz, Assistant Engineer, Chicago, Milwaukee & St. Paul Railroad, Chicago, Illinois.

Have adopted concrete slabs on all deck bridges. Trough for ballast. In one case rail directly embedded in concrete because of lack of headroom. Well satisfied with concrete slabs. For roadbeds considerable experimenting necessary to establish value of idea.

W. H. Penfield, Assistant to Vice-President, Chicago, Milwaukee & St. Paul Railroad, Chicago, Illinois.

Believes there are advantages in such a slab, but experiments are necessary and cost is exorbitant.

Samuel Rockwell, Consulting Engineer, New York Central Lines, Cleveland, Ohio.

In general, idea does not appeal. Only few places where it could be used to advantage. If slab is placed, it should be under ballast. Favors thin slab for drainage.

Lincoln Bush, Consulting Engineer (formerly Chief Engineer, D., L. & W. R. R.), New York City.

Explains concrete construction in New Bergen Hill Tunnel of Lackawanna Railroad. Concrete roadbed has stood up very well with a perfectly rigid surface having been in use under very heavy traffic for over eight years. There will be no pounding nor serious damage in rigid railroad track with proper maintenance of rolling stock, such as the avoidance of flat wheels. Favors rigid roadbed with longitudinal wall support under rails with creosoted block cushions for special service, such as tunnels and subways or where traffic conditions are severe.

Edward Gagel, Chief Engineer, New York, New Haven & Hartford Railroad Company, New Haven, Connecticut.

Unable to recommend concrete of any type as a slab between the ballast and rails, for the reason that modifications are too frequent to permit of any definite scheme.

W. A. Christian, Senior Roadway Engineer, Bureau of Valuation, Interstate Commerce Commission, Chicago, Illinois.

Track alinement would have to be permanent before concrete slab would be valuable. Embankments settle for many years. Expense a big obstacle.

W. J. Towne, Assistant General Manager, Chicago & Northwestern Railroad, Chicago, Illinois.

Very much interested, but could not see what would be gained. Believed concrete too rigid if in direct contact with concrete slab under high-speed trains. Expense prohibitive.

M. H. Wickhorst, Engineer of Tests, Rail Committee, American Railway Engineering Association, Chicago, Illinois.

The expense would be considerable. However, with a continuous concrete wall the rail could be designed merely as a head on which the wheels would roll.

W. H. Courtenay, Chief Engineer, Louisville & Nashville Railroad, Louisville, Kentucky.

Considers scheme impractical. Cost prohibitive. Would be of advantage for drainage, but embankments settle for long periods of time.

R. L. Cochran, Chief Clerk to Chief Engineer, Santa Fe Railroad, Chicago, Illinois.

Idea interesting and worthy of discussion, but hardly feasible within reasonable cost. Design should contemplate introduction of substance other than concrete, which would shatter next to rail.

P. M. LaBach, Assistant Engineer, Rock Island Lines, Chicago, Illinois.

For general use such construction too expensive, but under crossing frogs it could be used to advantage. Would eliminate drainage troubles. Ballast should be placed on slab.

E. Weideman, Structural Engineer, Union Station Company, Chicago, Illinois.

I believe that heavy traffic lines with an eventual future increase of locomotive axle loads may find concrete slabs as roadbed an economical and necessary solution.

Respectfully submitted,

COMMITTEE ON BALLAST.

REPORT OF COMMITTEE XI—ON RECORDS AND ACCOUNTS.

W. A. Christian, *Chairman;*
M. C. Byers, *Vice-Chairman;*
F. L. Beal,
G. D. Hill,
Lester Bernstein,
G. T. Kuntz,
H. Bortin,
Henry Lehn,
J. W. Fox,
J. H. Milburn,
B. B. Harris,
J. C. Patterson,
R. C. Sattley,
Huntington Smith,
H. M. Stout,
W. D. Wiggins,
Committee.

To the American Railway Engineering Association:

Your Committee on Records and Accounts respectfully submits the following report to the Twentieth Annual Convention on the subjects assigned by the Board of Direction, as follows:

(1) Make critical examination of the subject-matter in the Manual and submit definite recommendations for changes.

(2) Report on the use of small forms on cardboard or other suitable material for use of fieldmen in making daily reports, to the end that supervision may be facilitated and efficiency encouraged.

(3) Report on feasible and useful sub-divisions of the Interstate Commerce Commission "Classification of Investment in Road and Equipment" and "Classification of Operating Expenses of Steam Roads."

(4) Report on cost-keeping methods and statistical records.

(5) Report on a systematic arrangement for filing plans in connection with estimates.

(6) Report on additional definitions if necessary.

(7) Report on the following forms:
For Maintenance of Way and Structures.
For Construction.
For Records.

(8) Report upon forms for analyzing expenditures for assistance in controlling expenditures.

COMMITTEE MEETINGS.

The General Committee has not held any meetings during the year on account of existing conditions; the work being carried on by correspondence. Sub-Committees have held meetings at various times and places.

(1) REVISION OF MANUAL.

The subject-matter in the Manual has been considered by your Committee during the past year, but no changes are recommended at this time.

(2) USE OF SMALL FORMS ON CARDBOARD OR OTHER SUITABLE MATERIAL FOR FIELDMEN.

A series of small forms illustrating the practice of several roads was submitted in 1917, Vol. 18, pages 769-797, as being, in the judgment of the

Committee, suitable for the purpose for which they were designed. Your Committee has no further report to present, and suggests this subject be discontinued.

(3) SUB-DIVISIONS OF I. C. C. CLASSIFICATION OF INVESTMENT IN ROAD AND EQUIPMENT.

In a previous report your Committee submitted as information a discussion of changes in sub-divisions of the I. C. C. Road and Equipment Classification. The Committee reports progress on this subject for the present, and suggests that it be reassigned for the current year.

(4) COST-KEEPING METHODS AND STATISTICAL RECORDS.

Your Committee reports progress on this subject for the present. During the year your Committee has received from the Bureau of Railway Economics and leading publishing houses information on the subject of cost-keeping methods as applying to railroads.

In reply to circular letter, sent to the different railroads on this subject, thirty-five answers were received, of which one-third were accompanied with information in the nature of blank forms used in accounting records; another third indicated interest in the subject, and the remaining third stated their records were kept in accordance with the I. C. C. Classification.

In view of the changes taking place in the railroad situation during the past year—and we are still in the midst of this transition period—your Committee suggests that this subject be reassigned to it for the coming year. The Committee desires to place on record its appreciation and thanks to those who so kindly replied to its request for information.

(5) SYSTEMATIC ARRANGEMENT OF FILING PLANS IN CONNECTION WITH ESTIMATES.

The subject-matter is under consideration by the Sub-Committee, but the study has not progressed sufficiently to make a report at this time.

(6) ADDITIONAL DEFINITIONS.

On this subject your Committee reports progress.

(7) REPORT ON FORMS FOR

MAINTENANCE OF WAY AND STRUCTURES.

CONSTRUCTION.

RECORDS.

The work has progressed to a point where a general discussion seems essential for further advancement, but as all members have been excep-

tionally occupied this past year, such discussion has not taken place, and your Sub-Committee requests that the subject be again referred to it for the current year.

(8) FORMS FOR ANALYZING EXPENDITURES FOR ASSISTANCE IN CONTROLLING EXPENDITURES.

On this subject the Committee reports progress and requests that it be reassigned.

RECOMMENDATIONS FOR FUTURE WORK.

Your Committee recommends that all subjects assigned to it last year, with the exception of No. 2, be again referred to it for the current year.

Respectfully submitted,

COMMITTEE ON RECORDS AND ACCOUNTS.

REPORT OF COMMITTEE I—ON ROADWAY.

W. M. DAWLEY, *Chairman;*
J. A. SPIELMANN, *Vice-Chairman;*
J. R. W. AMBROSE,
H. E. ASTLEY,
C. W. BROWN,
S. P. BROWN,
B. M. CHENEY,
C. W. COCHRAN,
W. C. CURD,
PAUL DIDIER,
S. B. FISHER,
W. C. KEGLER,
H. W. MCLEOD,
C. M. MCVAY,
F. M. PATTERSON,
W. H. PETERSEN,
P. PETRI,
W. F. PURDY,
R. A. RUTLEDGE,
W. H. SELLEW,
J. M. SILLS,
W. P. WILTSEE.

Committee.

To the American Railway Engineering Association:

The following subjects were assigned by the Board of Direction to the Roadway Committee for consideration:

1. Make critical examination of the subject-matter in the Manual and submit definite recommendations for changes.
2. Subsidence under Embankment—Methods of determining extent, character and effect.
3. Shrinkage of Embankment—Select a number of specific instances, reciting all the conditions, such as locality, weather, foundation, character of filling material, height of fill, method of construction, etc., to be used as a guide in estimating shrinkage.
4. Report on prevention or cure of water pockets in roadbed.
5. Continue the study of unit pressures allowable on roadbed of different materials, co-operating with Special Committee on Stresses in Railroad Track.

Owing to the unusual conditions brought about by the war and other circumstances your Committee has been able to give consideration to subjects 3 and 4 only.

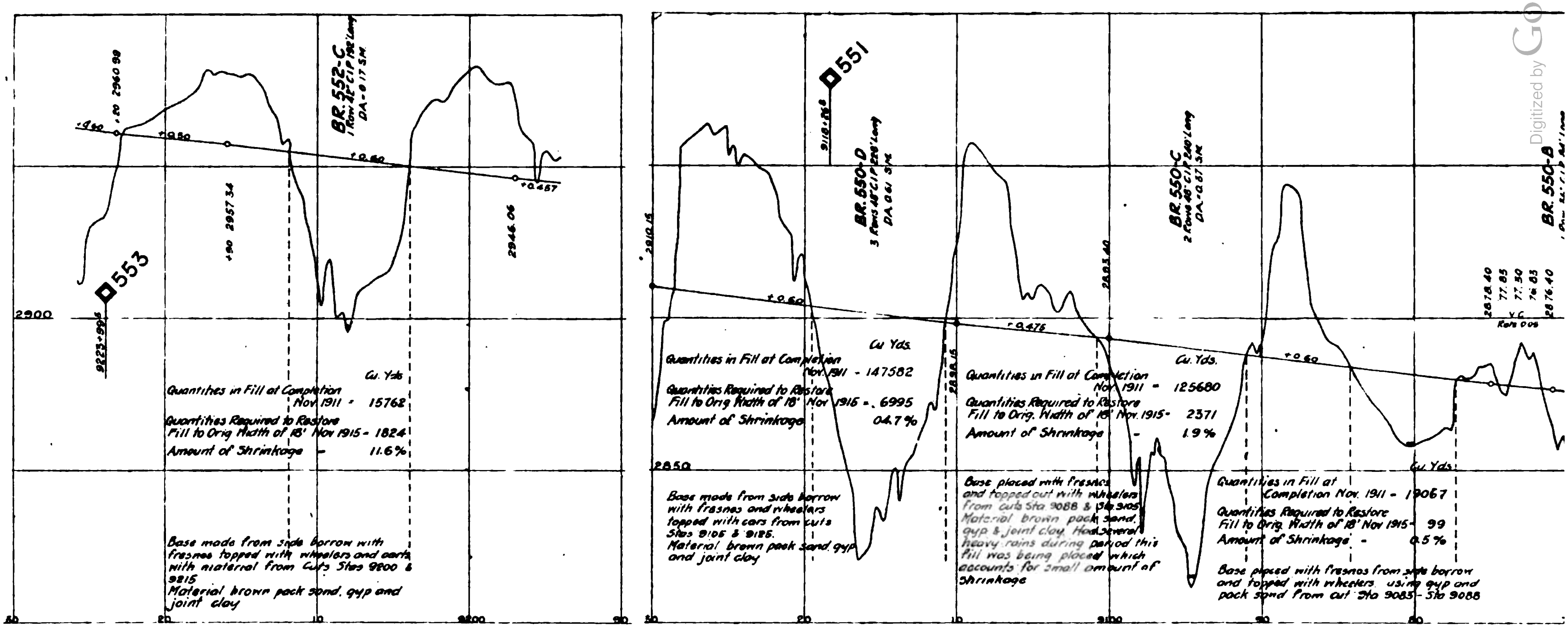
SUBJECT NO. 3.

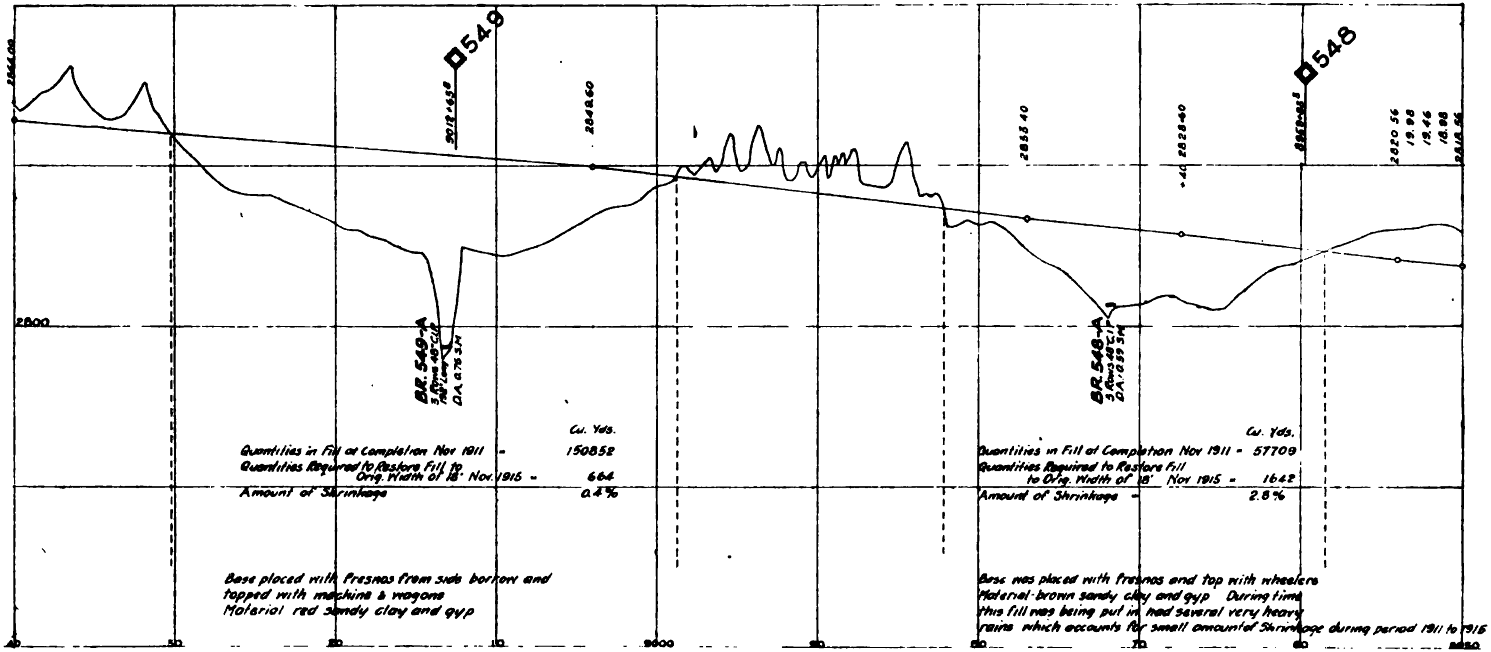
Your Committee submits as information the following eight profiles of specific instances of shrinkage of embankments on the Atchison, Topeka & Santa Fe Railway between mileposts 540 and 553, giving the percentage of material required to restore the several embankments to their original width after a lapse of four years' time.

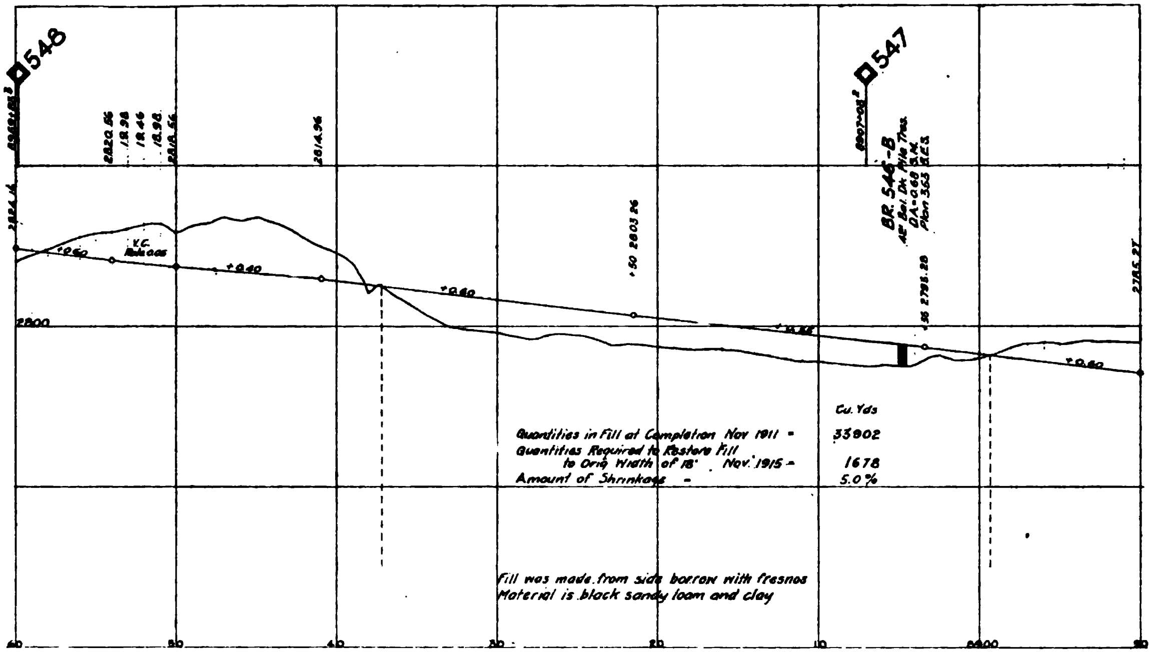
SUBJECT NO. 4.

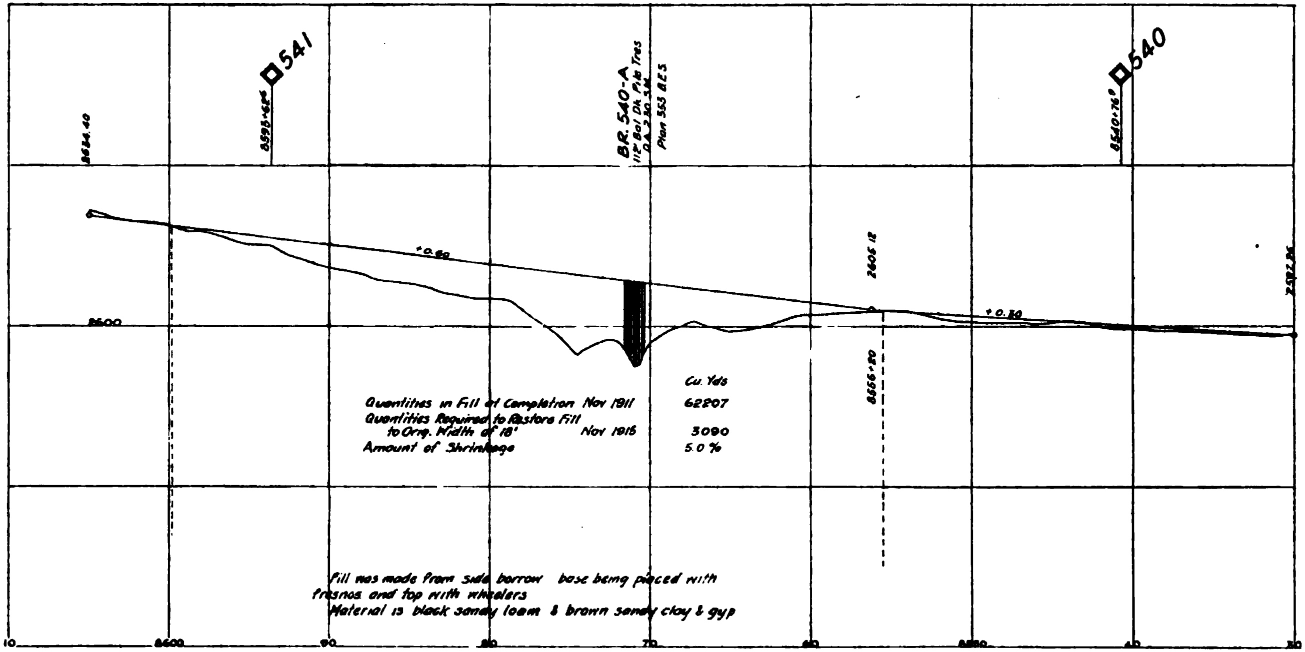
This subject is one which has been before your Committee for several years, and in 1914 a circular letter was sent to the different members of the Association, asking certain questions in regard thereto. This letter was as follows:

"The Board of Direction has assigned to the Roadway Committee for investigation 'Means for prevention of or cure of water pockets in road-


553
9223+99.5
+20 2960.98
+9.50
+90 2957.34
BR. 552-C
1 Row 42" C.I.P. 192' Long
DA - 0.17 S.M.
+0.60
2946.06
+0.457
2900
Cu. Yds.
Quantities in Fill at Completion Nov. 1911 - 15762
Quantities Required to Restore Fill to Orig. Width of 18' Nov. 1915 - 1824
Amount of Shrinkage - 11.6%
Base made from side borrow with fresnos topped with wheelers and carts with material from Cuts Stas 9200 & 9215
Material brown pack sand, gyp and joint clay
9200
2910.15
551
9118+26.8
BR. 550-D
3 Rows 48" C.I.P. 226' Long
DA 0.61 S.M.
+0.60
Cu. Yds.
Quantities in Fill at Completion Nov. 1911 - 147582
Quantities Required to Restore Fill to Orig. Width of 18' Nov. 1915 - 6995
Amount of Shrinkage 04.7%
2850
Base made from side borrow with fresnos and wheelers topped with cars from cuts Stas 9105 & 9125.
Material brown pack sand, gyp and joint clay
2898.15
+0.475
2893.40
BR. 550-C
2 Rows 48" C.I.P. 240' Long
DA - 0.57 S.M.
Cu. Yds.
Quantities in Fill at Completion Nov. 1911 - 125680
Quantities Required to Restore Fill to Orig. Width of 18' Nov. 1915 - 2371
Amount of Shrinkage - 1.9%
Base placed with fresnos and topped out with wheelers from cuts Sta. 9088 & Sta. 9105
Material brown pack sand, gyp & joint clay. Had several heavy rains during period this fill was being placed which accounts for small amount of Shrinkage
9100
+0.60
Cu. Yds.
Quantities in Fill at Completion Nov. 1911 - 19067
Quantities Required to Restore Fill to Orig. Width of 18' Nov. 1915 - 99
Amount of Shrinkage - 0.5%
Base placed with fresnos from side borrow and topped with wheelers using gyp and pack sand from cut Sta. 9083 - Sta. 9088
2878.40
77.85
77.30
76.83
2876.40
V.C.
Rate 0.05
BR. 550-B


2864.00
549
9012+63.8
2849.60
2800
BR. 549-A
3 Rows 48" C.I.P.
198' Long
D.A. 0.76 S.M.
Cu. Yds.
Quantities in Fill at Completion Nov 1911 - 150852
Quantities Required to Restore Fill to Orig. Width of 18' Nov. 1915 - 664
Amount of Shrinkage 0.4%
Base placed with Fresnos from side borrow and
topped with machine & wagons
Material red sandy clay and gyp
2833.40
+40 2828.40
548
8969+86.5
BR. 548-A
3 Rows 48" C.I.P.
D.A. 0.59 S.M.
2820 56
19.98
19.46
18.98
2818.56
Cu. Yds.
Quantities in Fill at Completion Nov 1911 - 57709
Quantities Required to Restore Fill to Orig. Width of 18' Nov 1915 - 1642
Amount of Shrinkage - 2.8%
Base was placed with Fresnos and top with wheelers
Material-brown sandy clay and gyp During time
this fill was being put in had several very heavy
rains which accounts for small amount of Shrinkage during period 1911 to 1916
40
50
20
10
9000
90
80
70
60
8950


548
547
BR. 546-B
2800
2820.56
19.98
19.46
18.98
2818.56
2814.96
+50 2803.26
+56 2795.28
2785.27
+0.60
+0.40
V.C.
Cu. Yds
Quantities in Fill at Completion Nov 1911 = 33902
Quantities Required to Restore Fill to Orig. Width of 18'. Nov. 1915 = 1678
Amount of Shrinkage = 5.0%
Fill was made from side borrow with fresnos
Material is black sandy loam and clay


541
8595+62.6
8684.40
BR. 540-A
112' Bal Dk Pile Tres
Plan 353 B.E.S.
540
8540+76.0
+0.80
2606.12
+0.30
8600
8656+20
Cu. Yds
Quantities in Fill at Completion Nov 1911 62807
Quantities Required to Restore Fill
to Orig. Width of 18' Nov 1915 3090
Amount of Shrinkage 5.0 %
Fill was made from side borrow base being placed with
fresnos and top with wheelers
Material is black sandy loam & brown sandy clay & gyp
10
8600
90
80
70
60
8550
40
30

bed.' To enable the Committee to consider this subject a reply to the following questions is requested:

"(1) When were water pockets first noticed by you? Was this before or after advent of heavy motive power?

"(2) Do you find there is an increased tendency at this time towards formation of water pockets on old operated lines?

"(3) Describe in detail the position in which you find the ballast in water pockets.

"(4) Do you find water pockets to be confined to embankment only or also in cuts?

"(5) Do you find water pockets prevalent in certain localities where soil conditions are unfavorable to satisfactory maintenance?

"(6) In your opinion, has method of surfacing and tamping track anything to do with their formation? Please describe methods.

"(7) What methods have you adopted for cure of pockets? Please describe in detail.

"(8) Have you found any way to prevent formation of pockets either in old or new track? If so, please describe.

"It is earnestly hoped that a full and detailed reply will be given to this circular, which will not only cover the points asked in the questions, but any other phases of the matter you deem important.

"Replies should be addressed to Chairman of Sub-Committee, Mr. W. C. Curd, Drainage Engineer, Missouri Pacific Railway, Railway Exchange Building, St. Louis, Mo., not later than November 15, 1914."

A large number of replies were received to this inquiry and the Sub-Committee of that year made a progress report, which is printed in Vol. 16, page 595, of the Proceedings of the Association. The Committee at that time was not ready to form conclusions either as to the best method of preventing water pockets or the best method of curing water pockets that exist.

We do not find that anything of particular interest along these lines has been developed since that report, except that of specially preparing the roadbed before laying track by means of rolling, an account of which is printed in Vol. 18, page 658, of the Proceedings.

It is desired, however, to report on this subject, and we have condensed and tabulated the replies made to the circular letter above referred to, and attach a copy of the replies. From these replies and our own experience along this line, we would recommend the following conclusions be adopted for inclusion in the Manual:

Conclusions.

(1) Water pockets have existed for many years in certain localities since construction.

(2) They have increased and become more noticeable since the use of heavier equipment and greater density of traffic.

(3) In water pockets the ballast has generally been beaten down into the roadbed and formed troughs under the track, the sub-ballast and

roadbed being pushed out laterally and sometimes raised, forming walls, to prevent the water draining from under the track.

(4) Water pockets exist in fills as well as cuts, but more generally in cuts of a clayey nature.

(5) They exist in localities where soil conditions are unfavorable to satisfactory maintenance, particularly in clay.

(6) Method of surfacing and tamping track has no particular effect in forming water pockets, but the class of material used as ballast does have considerable effect.

(7) Water pockets can be prevented in many cases by proper formation of roadbed and use of proper kind and depth of ballast, as follows:

(A) Where roadbed, in either cuts or fills, is composed of a more or less clayey material, after the work has been brought to a sub-grade all construction tracks should be removed and the sub-grade rolled with a road roller weighing about ten tons, to a uniformly smooth surface with either sufficient crown or side slope to shed water; any resulting depressions below sub-grade being loosened up with a plow and brought up to sub-grade by the addition of material of the same kind as that composing the roadbed; and then re-rolled.

After several years' use under traffic it may be necessary to cut through the shoulder of the sub-grade at frequent intervals to afford drainage, as the sub-grade under the track will settle several inches lower than the shoulder.

(B) Sub-ballast should be of engine cinder, screenings or other similar material, so as to prevent roadbed working up into the ballast proper. Stone ballast should not be used directly on top of clay or loam roadbed.

(C) Sufficient depth of ballast should be provided to insure even distribution of the load on the roadbed.

(D) Construction trains should not be run, if possible to avoid, over track laid on new roadbed without ballast. This drives the ties into the roadbed and forms depressions, which later on develop into water pockets.

(E) In wet cuts, sub-soil drains of vitrified bell and sewer pipe should be laid on a 4-inch well-tamped bed of engine cinders in deep ditches, with uncemented joints, and the trench then back-filled with same material as removed if at all porous, otherwise back-fill with engine cinder.

(F) Wet cuts of clay should have sufficient crown to drain properly and the surface should be smooth. Any back-filling necessary to make a smooth surface should be made of the same material as exists in the cut.

(G) In building new roadbed alongside existing tracks on same grades, care should be taken not to form new roadbed of impervious

material at a higher elevation than the original roadbed, but the new roadbed should be kept at or below this level so as to provide an outlet for the drainage through the existing ballast. This is particularly important on hill-side construction. If change in existing gradient is to be made, new roadbed for both tracks should be on same level.

(8) In curing water pockets the principal object is to provide proper drainage. This may be accomplished, according to localities, in several ways, as follows:

(a) In cuts, by means of sub-soil drains of vitrified bell and sewer pipe, laid in ditch or between tracks with uncemented joints. They should be laid at such depth as to be below any movement of the sub-grade and below the water to be drained. They should be below the frost line. Lateral drains of pipes or of cinder or stone may be made to tap the pockets if necessary. Pipe should be covered 12 inches or more with porous material, and then the trench should be back-filled with the same material as removed, if at all porous, otherwise use engine cinders for back-filling.

(b) In cuts were material is very soft to a considerable depth, a drain about 3 feet square may be provided of large stone, either in the ditch line or between tracks, and of sufficient depth to take the drainage.

(c) In cuts where material is soft to a great depth, old ties or bridge timbers may be driven just outside the ends of the ties. These serve to hold the roadbed in place and to some extent lower the water level, leaving the top surface of the roadbed more firm.

(d) On fills, water pockets should be tapped by lateral ditches and filled with porous material so as to drain.

(e) In many cases the material will have to be excavated and a bed of old timber, cinder or other material spread over the surface to provide sufficient area to prevent the further penetration of the ballast into the roadbed, and the ballast should then be replaced with good, clean material.

Director C. E. Lindsay has furnished your Committee an abstract of a report of the Commissioner of Public Highways of the State of New York for the year 1916 on "Frost Action," which is submitted as information.

FROST ACTION.

Abstract of report of Fred W. Sarr, Second Deputy Commissioner of Public Highways for year 1916, concerning maintenance of 6,048 miles of improved highway in state of New York, referring particularly to destruction by frost action of the equivalent of eighty-two miles of 16-foot road, analyzing the causes and offering certain theories as to frost action.

The field engineers who made the surveys of the broken pavements were requested to designate a reason or cause for the breakup, and of the reasons assigned 50 per cent. were accredited to poor drainage.

This answer is one that is most easily assigned and readily accepted as the cause of broken pavements which develop during the spring months.

This reason, however, will not explain why the roads break up in the spring and not during a protracted rainy period in the fall, or why they break up some seasons and not in others.

The conclusions of the writer are that the conditions favorable to broken pavements in the spring are a wet season the previous year followed by an open winter or one with repeated freezing and thawing; the effect of these conditions on a silt sand or soft clay produce an unstable condition when the frost finally leaves the ground, and if the pavement crust has not sufficient strength in itself to bridge over the unstable section and carry the traffic loads, there is but one answer—a broken pavement.

The act of freezing of the material forming the foundation of a pavement draws moisture from below. This is demonstrated by freezing of a reasonably dry earth surface which, after thawing, leaves a wet, muddy surface.

Following a wet season the level of the ground water is high, perhaps at the elevation of the bottom of the open ditches. The act of freezing draws this water up to the underside of the pavement which, if impervious, is heaved or raised by the expansion of the moisture by freezing. The frost goes out, but before the moisture can leach away, another freeze occurs, more moisture is drawn up, more heaving occurs. It is not uncommon to find pavements heaved four to six inches with not over eighteen inches of frost.

The expansion of water by freezing is about one-eleventh. It is, therefore, evident that the extreme heaving is due to something other than the expansion of the moisture which was naturally in the crust actually frozen.

We must, therefore, conclude that the act of freezing and thawing draws up, from the ground water level, moisture which accumulates under the impervious pavement in frost or ice, thereby lifting or heaving the pavement.

This action may be observed with many classes of soils, but only in certain cases will the pavement break through.

When the frost finally leaves the ground in the spring there is an accumulation of water in the frost-affected area, and with soils that of their nature by capillary attraction hold the moisture in suspension, they become semi-plastic and unstable. Soils that are not as suited to the capil-

Condensed Tabulation of Answers to Circular Letter of October, 1914.

RAILROAD.	When were water pockets noticed? Was it before or after advent of heavy motive power?	Is there an increased tendency at this time toward formation of water pockets on old operated lines?	Position of ballast in water pockets.	Are water pockets confined to embankments only, or also in cuts?
Duluth, South Shore & Atlantic. E. R. Lewis, Chief Engineer	Before	Yes	Top of roadbed concave in cross-section	Both
Great Northern R. R. J. R. W. Davis, Engineer M. of W.	Noticed for indefinite time. Have increased after introductory of heavy motive power. Frequency depends on material used	Yes	Under ends of ties where hardest tamping is done, depression as much as 4 feet, most cases 6 in. to 24 inches	Both
Southern. B. Herman, Chief Engineer M. of W. and Structures	Before	Yes	Found in cup shaped wedges, frequently forced to one side.	Both
St. Louis & San Francisco. F. G. Jonah, Chief Engineer	Existed to some extent for many years. Occur to a greater extent since heavy motive power	Develop at times, even on an old operated line	See cross-sections	Both, in many cases due to water pockets in cuts
Chicago & North Western. W. J. Towne, Asst. Gen. Manager	Many years—heavy power has not materially influenced the matter	No	Usually beaten down to center of embankment, often 3 feet deep or more	Confined to embankments as far as my experience goes
Canadian Pacific. A. C. MacKenzie, Engineer M. of W.	Since construction of road, have increased since advent of heavy motive power	Yes, due to increased traffic and increase in motive power	Under each railroad bed humpes at center and at end of ties	Both
Grand Trunk. M. S. Blaiklock, Engineer M. W.	Before, particularly after heavy power.	Yes	Ballast has forced the sub-grade material downward and outward thus forming two walls parallel to the track preventing escape of water	Both
Illinois Central. A. S. Baldwin, Chief Engineer	Before	Yes, with the advent of heavy power. Pockets exist where material supporting tracks will not hold up the increased loads	Ballast in water pockets forms troughs under the tracks, impond water causing churning and settlement of track	Both. Stone ballast put on a green roadbed has a tendency to eat its way into the roadbed and form water pockets
Kansas City Terminal. John V. Hanna	Before			Both
Hirman J. Slifer, Consulting Engineer, Chicago				

Condensed Tabulation of Answers to Circular Letter of October, 1914.

Are water pockets prevalent in certain localities where soil conditions are unfavorable to satisfactory maintenance?	Has method of surfacing and tamping track anything to do with their formation?	What methods have you adopted for cure of pockets?	Have you found any way to prevent formation of pockets either in old or new track?
Yes......................	Tamping and banking fine material on ballast shoulder creates pockets......	Cross drains of 4-inch farm tile. In some cases trenches filled with rock will answer............	Remove or drain with porous material.
Yes......................	Not to any very great extent..................	Use of tile or trenches filled with engine cinders or coarse gravel...........	Can't be prevented unless greater care and additional expense in construction of the roadbed. Suitable material.
Yes......................	Practically nothing.......	Driving piles or second-hand stringers and bridge ties close together just beyond ends of ties....	
Yes......................	May have something to do with formation of water pockets; believe practically all trouble is due to placing a greater load on the ballast than is warranted by the supporting power of the soil........	See attached separate sheets.................	No, other than to apply a sufficient depth of suitable ballast to distribute the dead load and live load so that the bearing on the sub-grade will lie within the supporting power limits of the sub-grade. This will require a much greater depth of ballast than is generally considered necessary.
Yes......................	Have not noticed that it has.	Drainage................	No.
Found only where sub-grade is of clay formation	Tamping will increase. In a number of cases water pockets are started when roadbed is first formed, by wheel tracks which are not filled in and the roadbed crowned before ballast is deposited..	Drainage—Where the pockets extend some distance and depth cut down roadbed on both sides of track to full depth of pockets, removing this material with scrapers and back filling with gravel.......	No, except new lines proper crowning of the roadbed before ballast is applied.
Yes, particularly in blue clay...................	Yes, improper tamping of ballast under ties causes water pockets. When the material under ties is not properly packed the ties churn and draw water...	Tap pockets, remove bad material and replace with good. Pipe drains have been beneficial.........	Use good material in embankment and make formation of ballast a water-shed. Good pipe drains in cutting with transverse lines if material is bad.
Yes......................	No.....................	Remove bad material and replace with good. Good drainage..............	New roadbed of uniform material and good drainage. Rock ballast or a coarse gravel ballast through which the water would pass very freely should not be used on green roadbed.
Yes......................	No.....................	Drainage to reach bottom of pocket or sufficient ballast to reach hard bottom.	Use impervious cementing sub-ballast.
....	....	Drainage................	

Condensed Tabulation of Answers to Circular Letter of October, 1914.

RAILROAD.	When were water pockets noticed? Was it before or after advent of heavy motive power?	Is there an increased tendency at this time toward formation of water pockets on old operated lines?	Position of ballast in water pockets.	Are water pockets confined to embankments only, or also in cuts?
St. Louis, Southwestern. C. D. Purdon, Chief Engineer.....	Before...........	....	....	....
Chicago & Eastern Illinois. L. C. Hartley, Chief Engineer.....	Before, increased with heavier power and traffic.....	Yes................	Varies............	Both................
Chicago Great Western. C. G. Delo. Chief Engineer.....	Before...........	Yes................	Forced down into embankment.....	Where soil is impervious to water and will not permit a moderate seepage.
Chicago & Alton. H. T. Douglas, Jr., Chief Engineer.....	Before, increased by heavy engines and other rolling stock	No noticeable increased tendencies..	Where these pockets occur is always due to insufficient depth of ballast or the ballast is very foul and where roadbed is not properly drained..	Both................
Missouri, Kansas & Texas. F. Ringer, Engineer M. W....	Before...........	Yes—due to introduction of heavier power	Sub-grade pushed out laterally and upward, ballast crowned down into the pockets thus formed.........	Most in cuts, however a great many in embankments........
Norfolk & Western. L. C. Ayers, Asst. Supt.	Before...........	No—90% have disappeared, water pockets natural.....	Ballast pushed out from under ends of ties, thin layers of clay mixed with ballast..........	Cuts and level ground only.............
Norfolk & Western. W. R. Dawson, Asst. to Gen. Manager...	Before, more pockets since advent of heavy power.....	Yes, when ballast is foul and compact under ties.........	Push out from under ends of ties......	Both, generally under low rail...........
Elgin, Joliet & Eastern. Arthur Montzheimer, Chief Engineer..	Not due to heavy motive power, due to the inability of the subsoil to carry weights imposed upon it....	Pockets formed on old lines due to poor drainage..........	Ballast wet where pockets are located.............	Both................
Bessemer & Lake Erie. F. R. Layng, Engineer of Track......	Before, more frequent since advent of heavy motive power.......	On old lines where wheel loads or density of traffic has increased, pockets have increased.....	See notes and sketches.........	Both................
Philadelphia & Reading. Division Engineer.........	Before, more acute since advent of heavy traffic.....	No; see explanation...	See note...........	Both................
Boston & Maine. F. A. Merrill, Acting Engineer M. of W..	Before...........	No.................	Coarse material at bottom and fine material works to top............	Largely in ledge cuts, although occasionally in embankments

Condensed Tabulation of Answers to Circular Letter of October, 1914.

Are water pockets prevalent in certain localities where soil conditions are unfavorable to satisfactory maintenance?	Has method of surfacing and tamping track anything to do with their formation?	What methods have you adopted for cure of pockets?	Have you found any way to prevent formation of pockets either in old or new track?
Yes	No	Drainage	
Yes	By frequent surfacing and tamping weak places in the original roadbed water pockets are often started or old ones made deeper and worse	Drainage and use of cinders until churning of track is stopped	To prevent pockets in new roadbed, holes to be filled with same material as remainder of grade, leaving the surface without depressions before the ballast is applied and proper drainage.
Yes	No. Train and engine loads cause of forcing ballast into soil	Drainage	First ballast track and earth embankment with fairly heavy ballasting sand, fine gravel or cinders—sand in preference.
Yes	No	Increase depth of ballast and provide drainage	Proper depth of ballast and drainage.
Yes	Think it will have an effect in forming pockets		Sufficient ballast to carry heavy power. Sufficient ditches in cuts. Good drainage.
Yes	No	Remove material and refill with stone or layer of thick boards; in some cases use poles, such as short crooked piling, bridge timbers, etc., place in such a way to form drain	Pockets natural. Can be overcome by proper draining and use of plenty of ballast.
Yes	Has much to do with formation	See file	12 inches of stone ballast and good drainage.
Yes	No	Cross drains 3 feet below water pocket	If drainage cannot be obtained, raise track.
Yes, such as in clay, etc	Yes	Drainage	Drainage, more and better ballast, stiffer ties, ties closer, heavier rail, better joints.
Yes	Not very much	Drainage and removing quicksand, etc., and replace with large stone	Proper crowning, sufficient depth between soil and sub-grade. Tile drains.
Yes	No	Drainage; in rock cuts remove earth and fill cobbles and coarse gravel	Sub-grade should be constructed with sufficient crown, so water can drain out freely; embankment to be compact before ballast is applied.

Condensed Tabulation of Answers to Circular Letter of October, 1914.

RAILROAD.	When were water pockets noticed? Was it before or after advent of heavy motive power?	Is there an increased tendency at this time toward formation of water pockets on old operated lines?	Position of ballast in water pockets.	Are water pockets confined to embankments only, or also in cuts?
Boston & Albany. F. B. Freeman, Chief Engineer..........	Before, since advent of heavy power, showing up more.	Yes, due to heavy power.............	Varies............	Both, particularly in boulder cuts.......
Wheeling & Lake Erie. R. J. McComb, Supt. of Track.....	Before...........	No................	Between rails and beneath rails and end of ties.......	Both................
New York, New Haven & Hartford. W. J. Backes, Engineer M. of Way............	Before...........	Yes................	Poor condition often churned to almost mud. Gravel ballast usually mixed with hardpan and clay............	Mostly in cuts but some in embankments............
Central Railroad of New Jersey. Jos. O. Osgood, Chief Engineer..........	Many years before..	Yes................	When dug out has been found to have pushed down into clay or other similar material of the subgrade...........	Both, more prevalent in cuts............
Lehigh Valley. E. B. Ashby, Chief Engineer..............	Before...........	No, where proper care is exercised........	Generally found in soft underlying material, in other words where there is no drainage outlet.............	Gen. speaking, are confined to cuts on embankments where the shoulders have been made of heavy impervious material.
Delaware, Lackawanna & Western. G. E. Boyd, Division Engineer..........	Before...........	Yes...............	Down in mud and soft material 4 feet to 5 feet deep.	Both...............
Erie Railroad. J. B. Dickson, Asst. Gen. Manager..........	Before...........	No................	Water pockets in center of ballast and lying directly below same......	Both...............
Delaware & Hudson. James MacMartin, Chief Engineer.....	Before...........	Only such as is due to increased weight of motive power......	Generally ground up in mud form.....	Both...............
Pittsburg. Shawmut & Northern. H. S. Wilgus, Engineer M. of Way........	No appreciable increase due to heavy power.....	No................	....	Both...............
L. E. & W. R. R. J. K. Conner, Chief Engineer..........	Before, has increased with heavier power..............	Some..............	Ballast driven down into soil.........	Both...............
New York Central & Hudson River. G. W. Vaughan, Engineer M. of Way....	After............	Yes................	Greater amount of ballast in center of track gradually decreasing towards the ends of the ties.......	Both...............

Condensed Tabulation of Answers to Circular Letter of October, 1914.

Are water pockets prevalent in certain localities where soil conditions are unfavorable to satisfactory maintenance?	Has method of surfacing and tamping track anything to do with their formation?	What methods have you adopted for cure of pockets?	Have you found any way to prevent formation of pockets either in old or new track?
Both....................	No....................	Drainage; some cases remove bad soil and fill with cinders and gravel ballast, some cases broken stone ballast..........	Spend more money on new and old lines.
Yes....................	Has considerable to do with formation of pockets where subsoil is not porous..................	Dig out to 3 feet below bottom of tie and refill with coarse riprap stone and use broken stone for ballast..................	Plank over sub-grade to a depth of 2 feet below bottom of tie and filling remainder with suitable ballast.
Yes, particularly where proper drainage cannot be provided...........	General opinion it does not, although track may become center-bound by tamping of ties and cause rolling motion under traffic....................	Proper ditching, renewal of ballast. In gravel ballast place tile drain below frost line and place loose stone around each joint and backfill ditch with ashes level with sub-grade................	Provide good sub-drainage and keep ditches clean. When installing drains, in some cases. Clean ashes from engine houses are placed in bottom of trenches before laying drain pipes as well as placing some around sides of drain.
Yes....................	No; of course when scanty ballast is used trouble is more prevalent.........	Drainage with ditches and drain tile 3 feet or 4 feet below base of rail	Adequate drainage.
Certain localities where the soil conditions are unfavorable to satisfactory maintenance..........	No, unless neglect in character of material used for ballast and raising track.	Dig out soft material and substitute hard, impervious material in sub-grade so as to form a crown and properly drain the roadbed beneath the ballast. Another method is draining with tile drains................	Properly crown sub-grade and drain. Good cinders and clean ballast form a good bed for stone ballast; no stone should be used unless the sub-grade is properly compacted.
Yes....................	No....................	Remove bad material and replace with cinders, etc.; also proper drainage....	See note.
Yes....................	No....................	Dig out and replace bad embankment with good material and drain......	Make cuts wide enough and drainage to take care of water in roadbed.
Yes....................	Longer ballast under track and more it has been tamped the more prevalent water pockets are..	Provide outlet for water..	Reinforced concrete sub-base, the top of which would be 18 inches below base of rail, with enough crowning in center to throw off the water.
Yes....................	....	Light ballast and farm tile blind ditches...........	
Yes....................	Some extent............	Tile drains..............	No.
Yes, but mostly in clay ground...............	No....................	Cutting down the shoulder outside of the ties with a roadbed spreader and reballasting the track.....	No.

Condensed Tabulation of Answers to Circular Letter of October, 1914.

RAILROAD.	When were water pockets noticed? Was it before or after advent of heavy motive power?	Is there an increased tendency at this time toward formation of water pockets on old operated lines?	Position of ballast in water pockets.	Are water pockets confined to embankments only, or also in cuts?
Rock Island. T. W. Patherson, Assistant Engineer..........	Before...........	Yes................	See blue print......	Both................
Chicago, Milwaukee & St. Paul, C. F. Loweth, Chief Engineer..............	Before...........	No................	Forming a trough...	Both................
Seaboard Air Line. J. C. Nelson, Engineer M. of W.......	Before...........	No; although find track more difficult to maintain at these places since use of heavy power.......	Gone down 3 feet to 5 feet below ties in pockets..........	See note............
Queen & Crescent Route. M. J. Connerton, Roadmaster.	1899; more since use of heavy power...	Yes................	3 feet to 5 feet deep in water pockets..	Both................
Louisville & Nashville. Jas. F. Burns, Asst. Engr. M. of W.....	Before; more serious since...........	Yes................	Mashed down to bottom of water pockets..........	Both. ....
Georgia Railroad. Valuation Engineer.	Before; increased since...........	Yes................	Ballast in pockets move outward....	Both...............
Nashville, Chattanooga & St. Louis. R. B. Trabue, Gen. Roadmaster...........	Before............	No................	....	Both................
International & Great Northern. O. H. Crittenden, Chief Engineer..........	Never noticed water pockets until advent of heavy power...........	Yes................	Egg shaped........	Both................

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Are water pockets prevalent in certain localities where soil conditions are unfavorable to satisfactory maintenance?	Has method of surfacing and tamping track anything to do with their formation?	What methods have you adopted for cure of pockets?	Have you found any way to prevent formation of pockets either in old or new track?
Yes	Doubt it, except end tamping of ties might tend to hold water in center of track	See note	See note.
Yes	We do not think so	See note	Drainage and heavy ballast.
As a rule, yes	No	See note	No
Yes	No	Drainage	See note.
Yes	Do not know that it has	Proper drainage and care for sub-grade	
Yes	No	Drainage	Proper drainage and ballasting.
Yes	No	Drainage	Drainage.
Yes	No	Drainage	Drainage.

lary action permit the moisture to sustain the pavement under moderate traffic.

The soil most productive of broken pavements is a silt sand found in the valleys. This material when examined with a microscope is found to be made up of round fragments of rock mixed with a varying quantity of silt or when dry an impalpable powder. This mixture of rounded sand grains mixed with the very fine powdered silt forms an ideal condition for the retention of moisture by capillary action, and when in a saturated condition is very unstable, and in extreme conditions is styled quicksand.

Traffic over the pavement crust where these conditions prevail causes the pavement to weave, depressing under the load and rising both front and rear; with moderate traffic the thin pavement crust may withstand the weaving without breaking through, the only result being a wavy surface after the moisture has finally leached away.

But with heavy loads traversing the highway during this unstable period the pavement first appears to buckle or bulge at frequent points, after which the destruction is fast; the pumping action of the passing load tends to force the plastic subsoil toward the vent at the bulge, where the pavement eventually breaks in what is termed a frost boil. This break is then extended at each end by traffic, until the small frost boil may extend fifty, one hundred or more feet in extent.

RECOMMENDATIONS FOR FUTURE WORK.

Your Committee recommends for next year's work a continuation of the consideration of Subjects 1, 2, 3 and 5.

Respectfully submitted,

COMMITTEE ON ROADWAY.

REPORT OF COMMITTEE XXI—ON ECONOMICS OF RAILWAY OPERATION.

F. W. Green, *Chairman;*
V. K. Hendricks, *Vice-Chairman;*
H. H. Brewer,
G. D. Brooke,
Ralph Budd,
M. Coburn,
C. E. Denney,
J. M. Egan,
L. C. Fritch,
U. E. Gillen,
M. V. Hynes,
C. M. Himmelberger,
W. J. Jenks,
P. M. LaBach,
Frank Lee,
J. de N. Macomb,
Jos. Mullen,
H. A. Osgood,
R. J. Parker,
J. H. Prior,
W. G. Raymond,
H. E. Riggs,
S. S. Roberts,
L. S. Rose,
E. F. Robinson,
Mott Sawyer,
Edward C. Schmidt,
J. E. Teal,
G. S. Waid,
C. C. Williams,

Committee.

To the American Railway Engineering Association:

The following subjects were assigned your Committee on Economics of Railway Operation by the Board of Direction:

1. Report on methods for increasing the capacity of a railroad, collaborating with Committee on Signals and Interlocking.
2. Collect data on operating costs from available sources, including rate case investigations, necessary to a complete analysis of operating costs, conferring with Committee on Economics of Railway Location.
3. Report on the effect of speed of trains upon cost of track maintenance.
4. Report on the economic length of operating districts.
5. Report upon the allocation of maintenance of way expenses to passenger and freight service.
6. Report on the reclamation and utilization of scrap material.

The Committee has been handicapped by the absence of its Chairman, Lieutenant-Colonel F. W. Green, who is in Army service in France, and by the absence of a number of other members in Army service, in addition to the fact that under the conditions which existed during the entire year very little time could be devoted by the membership to committee-work.

COMMITTEE MEETINGS.

The Committee held two meetings at Chicago, one on December 12, 1918, at which nine members were present, and one on February 6, 1919, at which eight members were present.

The work was divided among six sub-committees, their numbers corresponding to the numbers of the items assigned by the Board of Direction, as follows:

SUB-COMMITTEE NO. 1.

L. C. FRITCH, *Chairman;*
RALPH BUDD,
C. M. HIMMELBERGER,
U. E. GILLEN,
W. G. RAYMOND.

SUB-COMMITTEE NO. 2.

M. COBURN, *Chairman;*
C. E. DENNEY,
J. E. TEAL,
L. S. ROSE,
J. H. PRIOR.

SUB-COMMITTEE NO. 3.

MOTT SAWYER, *Chairman;*
FRANK LEE,
J. DE N. MACOMB,
S. S. ROBERTS,
C. C. WILLIAMS.

SUB-COMMITTEE NO. 4.

G. D. BROOKE, *Chairman;*
W. J. JENKS,
R. J. PARKER,
E. F. ROBINSON,
P. M. LABACH.

SUB-COMMITTEE NO. 5.

H. A. OSGOOD, *Chairman;*
JOS. MULLEN,
J. M. EGAN,
H. H. BREWER,
H. E. RIGGS.

SUB-COMMITTEE NO. 6.

M. V. HYNES, *Chairman;*
G. S. WAID,
EDWARD C. SCHMIDT.

SUBJECT NO. 2—COLLECTION OF DATA ON OPERATING COSTS.

A thorough study of existing cost data to determine how applicable they are to the solution of special problems with which this Committee is concerned would require a large force and a material expenditure, and the Committee feels that it should study the methods of analyzing costs rather than the costs themselves.

The Minnesota Rate Case made an epoch in cost accounting by insisting on more accurate information as a basis for rates. The "Arkansas Formula" was developed as a result of the decision, and was first used to find the cost of handling intrastate freight business. The "Formula" is a detailed method of assigning operating costs to the different services performed. Records are kept of actual work done by employes handling different kinds of business, and no expense is spared to make the results accurate and complete. General expenses are distributed on the basis of the other apportioned expenses. This method has been widely used in rate cases.

As an example, in 1916 the Central Freight Association made a very complete study of the Pittsburgh, Cincinnati, Chicago & St. Louis Railway, and the Cleveland, Cincinnati, Chicago & St. Louis Railway, in Ohio and Indiana, for a three months' period. This investigation took nearly a year for the subsequent collection of data, and cost about $263,000. It went further than previous studies in a supplementary investigation which separated the terminal costs of L.C.L. and carload freight.

With these complete investigations, there were collected various operating statistics, as well as cost figures—statistics which will be of value even though the cost data may not be applicable under present conditions.

We may find these figures of value when we have a definite problem in view.

Since these studies were made, an attempt has been made to develop simpler and less expensive methods, and formulas have been prepared which, while they cover only about one-third of the primary accounts, take care of about 85 per cent. of the expense. The items which are omitted are mainly the unimportant ones which cannot be easily classified and which can fairly be divided on the basis of other costs.

New operating statistics are being prepared under the direction of the U. S. Railroad Administration. It seems probable that the methods adopted will lead to valuable results, and it is to be hoped that the work may be continued and where found to be an improvement over old methods, it should be adopted by the Interstate Commerce Commission. It is not thought necessary here to discuss these new statistics. Reference is made to the article by William J. Cunningham, in the Railway Age of January 3, 1919, on page 43.

SUBJECT NO. 4—ECONOMIC LENGTH OF OPERATING DISTRICTS.

Sub-Committee No. 4 of the Committee on Economics of Railroad Operation is instructed to report on the economic length of operating districts.

Definition.

OPERATING DISTRICT—The section of a railroad extending between terminals where yard and enginehouse facilities are provided which is covered by slow freight trains in single runs, trips, turns or day's work.

The economic length or lengths of operating districts of a given railroad are those with which the sum of interest on first cost, depreciation and maintenance of road and equipment, and cost of operation, may be the minimum.

On account of varying speeds the economic length of engine districts for

(a) Through passenger trains,
(b) Local passenger trains,
(c) Preference or quick dispatch freight trains,
(d) Local and pick-up freight trains,
(e) Slow freight trains handling full engine rating,

are not always the same, and for this reason it is essential to draw a distinction between engine districts and operating districts. To a large extent the present practice is for passenger engines and engine and train crews to cover more than one operating district in a turn or day's work

either by longer straight-away runs or by doubling one or more operating districts or portions thereof. To a considerably less extent the same is true of fast freight trains, and local and pick-up freight trains frequently have runs shorter than the operating districts. Therefore, in determining the economic length of operating districts it will be sufficient to consider the term "operating district" as applying only to slow freight trains.

The factors affecting the length of operating districts of existing lines are:

(1) Location of existing yard and enginehouse facilities,
(2) Topographical conditions affecting the construction of new yards and enginehouse facilities,
(3) Character of grade line,
(4) Capacity of railroad for handling business to be moved,
(5) Density of (a) passenger traffic: (b) fast freight traffic: (c) slow freight traffic,
(6) Location of labor supply and of housing facilities of employes,
(7) Location of connections with important feeders where there is heavy transfer of traffic from one line to another, commonly termed "gateways."

All of these except No. 1 apply equally to new lines to be constructed except that the quantity of traffic frequently has to be estimated rather than determined from actual records.

The change in length of operating districts on existing lines has in the past been brought about by existing yard and terminal facilities being outgrown and on account of their inadequacy causing serious congestions of traffic rather than by any other cause. There are very few cases, if any, of new terminals on existing lines having been established solely for the purpose of changing the length of operating districts to promote economy. Usually a terminal becomes congested and topographical conditions are such that it is not practicable to increase its capacity. After a study of the situation it is found advisable to build a terminal in a new location, and this changes the lengths of the operating districts.

The disposal of existing terminal properties, the cost of new terminals and the breaking-up of established places of residence of employes are questions of such importance that it is rarely the case that any considerable change in the length of operating districts on an existing road has been justified alone by the resulting economies, and it is not possible to establish any rules or formulas which can be followed with any degree of certainty.

Aside from the questions of providing facilities for increased business, the principal items of operating and maintenance expense affected by the length of operating districts are:

(1) Wages of train and engine crews,
(2) Fuel and supplies for engines,
(3) Cost of dispatching engines,

(4) Cost of switching at additional terminals,
(5) Train dispatching and telegraph expenses,
(6) Maintenance of yards and engine terminals,
(7) Maintenance of locomotives (locomotives required, both road and yard, increase as the number of operating districts increase),
(8) Inspection and maintenance of cars, as affected by switching at additional terminals.

Take as a simple example a railroad of 500 miles operated under

Scheme A—Four operating districts of 125 miles each,

Scheme B—Five operating districts of 100 miles each.

(1) Under favorable conditions many freight trains will cover the 100-mile districts in from six to eight hours and a part of the wages of train and engine crews will be for "constructive" hours, and hence unproductive. With 125-mile districts this will not be so, or there will be less of it, and the wages of train and engine crews will be reduced accordingly, excepting as to such overtime as might be made on a longer district.

(2) Then if freight trains move at an average speed of 12½ miles per hour between terminals it will take a locomotive

$$\text{Scheme A} — \frac{500}{12.5} + 6 \times 4 = 64 \text{ hours}$$

$$\text{Scheme B} — \frac{500}{12.5} + 6 \times 5 = 70 \text{ hours}$$

to move a train over the 500 miles, one way. It will therefore require

$$\frac{70 - 64}{64} = .09375 = 10 \text{ per cent. (approximately)}$$

more road locomotives with Scheme B. Switching at the additional terminal will require at least two switch engines, so that if 60 road engines are required with Scheme A, then $60 + .10 \times 2 = 8$ additional engines will be required with Scheme B and the cost of fuel and supplies for these engines will be additional expense with this scheme.

(3) With Scheme B there will be 6 terminals, 4 intermediate, while with Scheme A there will be 5 terminals, 3 intermediate. The number of engine dispatchments under Scheme B will be approximately one-fifth more than under Scheme A and an additional supervisory and working force will be required, embracing ashpit, engine house, coal dock, power house and miscellaneous labor.

(4) Incident to the additional intermediate terminal under Scheme B there will be a certain amount of switching and a force of yardmasters, yard-clerks, switchmen, etc., required, adding to the expense of operation under this scheme.

(5) On account of there being an additional operating district another set of train dispatchers will be required under Scheme B and the additional terminal will add at least one telegraph office.

(6) The yard tracks, buildings and appurtenances of the additional terminal under Scheme B will have to be maintained and will add to this expense approximately one-fifth.

(7) There will be, as developed above, 6 road and 2 yard locomotives more required under Scheme B. These will have to be maintained at approximately the average cost of maintenance of all locomotives under Scheme A.

(8) A force of car inspectors will be required at the additional terminal and there will be a certain amount of damage to equipment in switching there, requiring repairs to the cars. This will add to the cost of repairs to cars under Scheme B.

This indicates briefly the result on the cost of operation of the establishment of additional terminals, so long as the lengths of the operating districts are held within practicable limits. However, the exercise of care and good judgment is necessary in making the decision between very long or moderately long districts. If the districts are very long, the average time of the crews on the road will be too great and there will be great likelihood of having to relieve them to avoid violations of the Hours of Service Law. Moreover, the factors affecting the length of operating districts Nos. 2 to 7 inclusive, page 434, have such an important bearing on the location of terminals and the economic length of operating districts that it is plainly evident that each case presents a problem in itself, which can be solved correctly only after a careful study of its own peculiar conditions. There are, however, certain principles which should be kept clearly in mind in determining the economic length of operating districts. These may be stated as follows:

(a) The number of terminals at which trains are switched and engines dispatched has a direct bearing on the cost of operation and should be a practicable minimum.

(b) It is advantageous to so locate terminals that locomotives will haul full tonnage rating over the entire operating district.

(c) It is advantageous to locate terminals at the intersections of natural railroad routes which will develop into important gateways.

SUBJECT NO. 6—RECLAMATION AND UTILIZATION OF SCRAP MATERIAL.

The Committee report on this subject is submitted as "Appendix A," as a matter of information.

PROGRESS REPORTS.

The Committee reports progress on Subjects 1, 3 and 5.

CONCLUSIONS.

The Committee recommends the acceptance of this report as information, it being considered unnecessary to insert any portion of the report in the Manual at this time.

RECOMMENDATIONS FOR FUTURE WORK.

The Commitete recommends the reassignment of Subjects 1 and 5 for the coming year, together with a modification of Subjects 2 and 3, the four subjects recommended being as follows:

(1) Report on methods for increasing the capacity of a railroad, collaborating with the Committee on Signals and Interlocking.

(2) Report on method of analyzing costs, for the solution of special problems with which this Committee is concerned.

(3) Effect of speed of trains upon cost of operation. (This year's subject covered effect upon track maintenance only.)

(4) Report upon the allocation of maintenance of way expense to passenger and freight service.

Respectfully submitted,

COMMITTEE ON ECONOMICS OF RAILWAY OPERATION.

Appendix A.

RECLAMATION AND UTILIZATION OF SCRAP MATERIAL.

Within the past four years there has been an advance in the cost to railways of every class of material necessary to be used for the purposes of maintenance and operation. The increase has in some instances amounted to several hundred per cent. Therefore, the question of reclaiming and conserving material is of vital importance to the economical operation of railways.

Only a few years ago the reclaiming of scrap was unknown in the railroad field. The railroads were very wasteful and indifferent with one of their largest assets—Materials. It is true that the large railroad systems assorted all scrap and believed they were getting good prices for this material, but it took the scrapdealers to start the reclaiming and reselling of the good material back to the railroads. A large number of railroads sold their accumulation of scrap unassorted; large quantities of unusable material cast aside by mechanics in repairing rolling stock found its way to the scrap pile.

The reclamation of scrap material is receiving considerable attention. The large railroad systems have puddling furnaces and rolling mills in the Reclaiming Department. The successful operation of a reclaiming plant requires a careful study of the work and it is very important that a competent and practical man is in charge for careful supervision and inspection, that the work of reclamation is not overdone or carried to extreme, that the cost will not exceed the cost of new material and that there is no reclaim of a large quantity of material that might not be needed.

That reclamation work may have its value, it is absolutely essential that careful cost records be maintained, otherwise in many cases the saving would be on the wrong side of the ledger. The actual cost of repairing an article must be based on the value of the material used, labor, shop expense and supervision; the material to be charged out at the market value as scrap; labor charge at the actual labor cost of doing the work; the shop expense and supervision are proportionate charges. After the cost of an article has been obtained, it is to be deducted from the value of the article as new, and this difference represents the saving effected. If the cost exceeds the value of the article as new, there is a loss, and if this continues to show on the shop order the repairing of the article is discontinued.

There is no item that should receive greater care or attention than the reclamation of scrap. The railroad officers to-day realize the great value of material returned to service that formerly was sold as scrap with the saving annually of thousands of dollars.

The reclamation of material started with the straightening and rethreading of bolts, but now all classes of work are done from tinware to the welding of broken locomotive frames, cylinders, fire-boxes, etc.,

and it not only represents the saving of the material, but also makes a greater saving in time saved in making repairs by the oxy-acetylene and the electric arc welding process and keeping the power and other equipment in service.

One of the largest net savings in the operation of a reclamation plant is the straightening and rethreading of bolts and nut tapping. No material is more generally used in the maintenance of railway equipment than bolts, nuts and washers. The annual expenditure of these commodities is very large and the question of reclamation is an important one. However, the handling of scrap material and the essential operations require a careful study together with a plant so arranged as to eliminate all unnecessary handling and as far as possible to handle material in quantities; also only necessary machine tools should be installed that can be kept in constant use, such as shears, power hammer, smith forges, forge furnace, small bending machine, bolt threading, nut tapping, punching machines, oxy-acetylene and electric welding, car brass and rebabbitting and boring machines, leaving the re-rolling machines for the very large plants only, where the accumulation of large quantities of wrought scrap suitable for re-rolling purposes warrants the installation of a rolling mill and furnace where scrap iron can be heated and rolled in billets and slabs, bars and shapes. The reclamation work does not begin at the plant but it is the duty of every employe using material to conserve it the same as if it were his own property.

The reclamation of scrap must progress even on the short line roads. About three years ago a small railroad started a reclamation plant on a small scale and below we give some of the results obtained:

For bolts and nuts a small plant was installed with nut tapping, bolt threading and bolt straightening and cut-off machine. This plant is kept constantly at work. All material when completed is returned to the storehouse and placed in bins with new material. This department is in charge of the storekeeper. An electric welding unit was installed and circuits with plugs located throughout the locomotive shop and enginehouses. Oxy-acetylene floor was located in the smith shop for welding and building up of the heavy castings, such as draw-bars, body bolsters and miscellaneous work. This department is under the supervision of the smith foreman. An operating plant is located in car or rip yard for the same work to avoid rehandling and save the distance from scrap dock, which is adjacent to the smith shop. All material from the dock goes, after inspection and assortment, to the smith shop floor, when the material is promptly repaired and returned to the Store Department. There are in use seven portable oxy-acetylene outfits for use in quick repairs on rip tracks and in shop and enginehouses. It is found that this process for repairs, welding, etc., is indispensable, and has greatly reduced time on work done, and shows from records kept the first year in use (1916) a saving in cost of labor and material of over $10,000 to this company. At the start some trouble was had on account of inex-

perienced operators. An arrangement was made with the Railroad Oxy-Acetylene Company of Chicago, who sent an instructor, with the result that the men have become extremely proficient in the art of welding. Attached hereto are statements showing just what was accomplished during the first year of reclaim work when the men did not thoroughly understand the art of welding. These statements are remarkable for that reason. There are two hundred different articles now reclaimed which formerly were sold as scrap.

STATEMENTS.

"A"—Statement indicating cost of journal bearings rebabbitted as compared to cost of new bearings and saving effected.

"B"—Statement indicating usable material reclaimed during October and November from scrap dock and again placed back into service and value of same.

"C"—Statement indicating material reclaimed through oxy-acetylene welding process, which otherwise would have been scrapped and value of same.

Note on statement "A" that for the five months, August to December, inclusive, saving of $2,226.36 has been effected by the use of car brass rebabbitting and the boring as against what we would have had to pay for the same material if purchased in the open market or under contract. The equipment installed for this reclaim work cost $360.00.

On statement "B" it will be noted that during the months of October and November material in value amounting to $804.30 has been put back in service. If sold as scrap we could not have realized to exceed $200.00. Based on these figures a saving of $5,000 or more on material reclaimed ought to be effected during the year 1917. The year 1917 shows a saving on reclaimed material of over $8,000.00.

Statement "C" indicates items welded during the period February 25 to March 31, 1916, and shows a saving of $224.00 on material that otherwise would have been sold or scrapped. The saving during the year 1916 shows approximately $5,800.00 effected. For heavy welding work there is no question but that welding of broken parts is entirely successful. There was a case of broken cylinder in new locomotive which was welded successfully, a large section broken, costing $58.00, labor and material; the saving effected was $1,150.00. The locomotive was out of service forty hours, otherwise it would have been necessary to hold the engine for new cylinder and saddle for shipment from the factory. The process embraces every conceivable item of casting, welding and building up broken or worn parts of material in the service and welding fire-boxes without tearing them down as formerly for patching.

It is also found the oxy-acetylene for cutting and welding is of great service for use on the wrecking crane for cutting steel cars and other parts when badly damaged in wrecking. Considerable time has been saved by its use. There is no limit to the use that the oxy-acetylene can

be put to. This plant has not tried the welding on switch points and frogs, as it is understood no good results have been obtained. This is very important and experts are experimenting along these lines. A great saving will result if the welding of broken parts of frogs and building up switch points without removing from the track could be satisfactorily accomplished.

The electric welding outfit is used for light welding, work flues, etc. The capacity of the machine is 150 amp. and is too light for heavy welding. For general railroad work a machine of 600 amp. capacity, with four operating leads, is suggested. However, the oxy-acetylene process is superior for railroad use. The portable outfits can readily be moved to the work and have been giving excellent results. Perfect work has been accomplished with the electric machine, but only when in the hands of expert operators who are to be found with the manufacturers of the machines. The trouble is in the control of the arc, to get a constant heat, especially is this true for heavy welding; it requires more expert handling than the oxy-acetylene process.

The total cost to equip this Reclaiming Department was $4,000.00. No new buildings were required and the layout of shop and yard is such that this work can be handled as economically as with a centrally located plant for the quantities handled. It is understood for larger reclaiming plants, with double the quantities of material handled, it would be necessary to have a separate plant for the reclaiming of scrap material.

This shows what can be accomplished on one division, using sixty locomotives and two thousand cars. On a large railroad a saving should be many times what is shown on attached statements.

STATEMENT "A"

o th 1916	Size 4½x8 Weight		Size 5x9 Weight		Size 5½x10 Weight		Value		Cost Re-Babbitting Moorefield	Saving Over New
	New	Scrap	New	Scrap	New	Scrap	New	Scrap		
Aug.....	1967	1525	....	....	187	140	$ 525.04	$ 251.62	$113.90	$159.51
Sept....	2863	1994	2708	2000	1733	1300	1835.13	926.45	324.85	583.83
Oct.....	2996	2087	1820	1344	2373	1780	1914.07	911.93	427.85	574.29
Nov....	1632	1136	1842	1360	1680	1260	1417.35	713.64	348.20	355.51
Dec.....	1646	1013	2578	1904	2000	1500	2014.90	1092.48	369.20	553.24
							$7706.49	$3896.11	$1584.00	$2226.38

Value, new all brasses......................		$7706.49
Value, scrap all brasses.......	$3896.11	
Cost re-babbitting all brasses,	1584.00	5480.11
Saving for 5 months.........		$2226.38

Statement "B."

Material Reclaimed During the Month of October.

10	6-in. Springs	350 lbs.		
8	8-in. Springs	360 lbs.		
10	7-in. Springs	400 lbs.		
		1,110 lbs.	@ $ 2.81¼ cwt.	$ 31.22
268 lbs.	C. I. Washers		1.65 cwt.	3.42
367 lbs.	Floor Washers		.02 lb.	7.34
10	Air Hose		.73	7.30
7	Knuckles		2.80	19.60
3	Car Brass	30 lbs.	.24	7.20
12	Door Guides		.46	5.52
1	Steam Heat Valve		16.65	16.65
2	Main Rod Brass	70 lbs.	.18	12.60
1	Tripple Valve		7.50	7.50
12	Brake Shoes	240 lbs.	32.50 G. T.	3.48
8	Knuckle Pins		.31	2.48
426 lbs.	Mixed Nuts		3.50 cwt.	14.91
198 lbs.	Mixed Washers		2.15 cwt.	4.26
30 lbs.	⅜-in. Bolts		1.50 cwt.	2.25
240 lbs.	½-in. Bolts 6-8		1.91 cwt.	4.58
890 lbs.	⅝-in. Bolts 5-21		2.91 cwt.	25.90
2655 lbs.	¾-in. Bolts 3-22		5.91 cwt.	52.20
6875 lbs.	⅞-in. Bolts 6-23		8.05 cwt.	158.18
1288 lbs.	1-in. Bolts 9-21		9.40 cwt.	30.27
760 lbs.	1⅛-in. Bolts 7-20		10.05 cwt.	19.10
				$435.96

Material Reclaimed During the Month of November.

4055 lbs.	⅞-in. Bolts 5-21		@ $ 8.05 cwt.	$133.21
982 lbs.	⅝-in. Bolts 5-10		2.91 cwt.	25.95
1757 lbs.	¾-in. Bolts 6-18		5.01 cwt.	34.57
526 lbs.	½-in. Bolts 4-13		1.91 cwt.	30.14
810 lbs.	1-in. Bolts 6-18		9.40 cwt.	18.19
655 lbs.	1¼-in. Bolts 7-15		10.40 cwt.	13.62
15	Air Hose		.73	10.95
20	Brake Shoes	200 lbs.	32.50 G.T.	4.20
1398 lbs.	Nuts		3.50 cwt.	48.93
13	Brake Hangers	104 lbs.	.04	4.16
560 lbs.	Washers		2.15 cwt.	12.04
35	Brake Shoe Keys	40 lbs.	3.50 cwt.	1.40
4	Cut Out Cocks, 1-in.		.90	3.60
1	Knuckle		2.80	2.80
4	Knuckle Pins		.31	1.24
16	Car Springs No. 720		2.81¼	20.24
50	Clevises		.05	2.50
				$368.34

Material reclaimed during the month of October	$435.96
Material reclaimed during the month of November	368.34
Grand Total	$804.30

STATEMENT "C."

SAVING EFFECTED FEBRUARY 25 TO MARCH 31, 1916, BY USE OF OX-WELD CUTTING AND WELDING OUTFIT AND OTHER RECLAIM METHODS INTRODUCED DURING THE YEAR 1916.

Items.	*Labor.*	*Ox-weld Cost.*	*Cost Under Old Method.*	*Saving.*
9 Drawbars	$ 5.53	$ 13.00	Scrap	$ 36.00
Engine frame weld	1.92	2.69	$8.00	3.69
6 Drawbars	2.85	8.65	Scrap	12.60
2 Engine drawbars	8.75	1.38	4.32	2.77
1 Freight car truck bolster	1.84	3.58	7.60	2.18
4 Drawbars	1.38	8.40	Scrap	2.28
Car end sill	.615	.54	Scrap	3.20
Locomotive side rod plug	.18	.34	2.10	1.58
Eng. 152 tank center plate	.75	2.65	Scrap	1.85
Car truck	.615	1.82	Scrap	11.32
Machine repairs	.615	.60	Scrap	2.85
Pedestal car work	.945	3.40	4.44	6.60
Freight car bolster	6.76	5.50	Scrap	9.74
Engine truck box	1.23	.80	Scrap	1.22
Machine repairs	.31	.71	1.71	.69
3 Freight drawbars	1.85	2.00	Scrap	5.15
Coach seat braces	3.75	.40	Scrap	1.00
4 Truck bolsters	7.60	25.00	Scrap	9.00
Miscellaneous tools	4.20	18.80	Scrap	35.00
Freight car channel posts	1.85	2.00	Scrap	15.00
Car bolster	1.02	2.80	5.20	1.38
3 Draft lugs, freight cars	1.82	1.80	Scrap	4.00
Eng. 1466, transmission bar	.55	1.60	4.25	2.70
Eng. 1466, valve rod	.60	1.00	2.00	.40
Freight car bolster	1.30	5.20	Scrap	12.00
Eng. 1469, trailer truck	2.40	1.20	12.00	4.80
3 Truck bolsters	2.20	10.40	Scrap	36.00
	$63.43	$126.26		$224.40

Ox-weld cost includes gas and equipment used.

Cost under old method represents cost of repairing before present reclaiming methods were introduced. "Scrap" indicates material that formerly could not be reclaimed.

Saving represents net saving due to improved methods, making due allowances for scrap values.

REPORT OF COMMITTEE IV—ON RAIL.

G. J. Ray, *Chairman;*	H. B. MacFarland, *Vice-Chairman;*
E. E. Adams,	Howard G. Kelley,
J. A. Atwood,	R. Montfort,
A. S. Baldwin,	A. W. Newton,
W. C. Barnes,	J. R. Onderdonk,
Chas. S. Churchill,	H. R. Safford,
W. C. Cushing,	J. P. Snow,
G. M. Davidson,	F. S. Stevens,
Dr. P. H. Dudley,	E. Stimson,
J. M. R. Fairbairn,	R. Trimble,
L. C. Fritch,	F. M. Waring,
A. W. Gibbs,	M. H. Wickhorst,
J. D. Isaacs,	*Committee.*

To the American Railway Engineering Association:

Your Committee on Rail respectfully submits herewith its report to the Twentieth Annual Convention.

The subjects assigned the Committee for 1918 by the Board of Direction for investigation and report were as follows:

1. Make critical examination of the subject-matter in the Manual, and submit definite recommendations for changes.

2. Report on rail failures and present statistics and conclusions as to causes and submit suggestions for improvement.

3. Continue special investigations of rail.

4. (a) Report on details of manufacture and mill practice as they affect quality of rail.

   (b) Continue research on the possibility of various improvements in methods of manufacture of steel rail.

5. Make critical study of joint bars from the standpoint of design and material, together with laboratory tests, including strain-gage measurements after having established a uniform method of comparative testing.

6. Report on relative value of material for joint bars, quenched only versus quenched and tempered, and whether it is most advantageous to quench in oil or water.

7. Report on rational relation between intensity of pressure due to wheel loads and resistance of rail steel to crushing and deformation.

8. Continue investigation and development of methods of inspection

9. Report on Federal and State Commission requirements.

10. Report on extent of use of Frictionless Rail, and results obtained therefrom.

Meetings were held in 1918 as follows: New York, May 21, with 16 present; New York, October 2, with 16 present; Chicago, November 21, with 16 present; New York, December 10, with 19 present.

(1) REVISION OF MANUAL.

The specifications for steel rails are in need of revision in the light of knowledge gathered in recent years and we give in Appendix A specifications which are submitted for consideration and discussion during the coming year. A number of changes have been made from the present specifications in the Manual, all of which should be given careful thought, but mention may be made of the following:

a. The manganese is raised 10 per cent. in both lower and upper limits in open-hearth rails, making the proposed requirement .70 to 1.00 per cent.

b. For open-hearth rails 111 lbs. per yd. and over the carbon is made .67 to .80 per cent., an increase of .05 per cent. for the heaviest class of rails.

c. For open-hearth rails the acceptance analysis is made on a sample from the finished rail instead of the ladle test ingot.

d. The bending of the rail in the physical testing may be accomplished by either the drop test or the quick bend test (hydraulic bender), as agreed upon in the contract.

e. The elongation is required to be at least eight per cent. in one inch instead of six per cent.

f. Three test pieces for bending are selected from each heat of open-hearth rails and all three are required to meet the requirements.

(2) RAIL FAILURE STATISTICS.

The statistics covering rail failures for the period ending October 31, 1917, were issued in Bulletin 209 for September 1918. (See Appendix E.) The average failures per 100 track miles of the rollings for the several years, including both Bessemer and open-hearth rails, are given herewith. This summary includes statistics from reports for the years 1913 to 1917 inclusive.

Year Rolled.	*Years Service.*				
	1	2	3	4	5
1908	....	....	.....	.....	398.1
1909	....	....	.....	224.1	277.8
1910	....	....	124.0	152.7	198.5
1911	....	77.0	104.4	133.3	176.3
1912	28.9	32.1	49.3	78.9	107.1
1913	12.5	25.8	44.8	69.5	.....
1914	8.2	19.8	32.9	.....	.....
1915	8.9	19.0	.....	.....	.....
1916	11.8	....	.....	.....	.....

It will be noted that the 1908 to 1912 rollings show successively decreased numbers of failures compared on a basis of five years' service, and the rollings of 1913 and 1914 also show successively decreased failures when compared on a shorter period of service. The more recent or "war-time" rollings, however, are not starting out so well, but what the final performance will be can only be told after they have been in service a sufficient length of time.

(3) SPECIAL INVESTIGATIONS.

During the year special reports have been presented by the Rail Committee as follows:

No. 71. Transverse Fissure Rails on Pennsylvania Lines. Heat 31531, by M. H. Wickhorst. (Bulletin 209.) (See Appendix C.)

No. 72. Interior Fissure Rails on the Baltimore & Ohio Railroad, Heat 5X157, by M. H. Wickhorst. (Bulletin 209.) (See Appendix D.)

No. 73. Rail Failure Statistics for 1917, by M. H. Wickhorst. (Bulletin 209.) (See Appendix E.)

No. 74. Transverse Fissure Rails on Delaware, Lackawanna & Western Railroad, Heat 27314, by M. H. Wickhorst. (Bulletin 209.) (See Appendix F.)

No. 75. Tests of Splice Bars at Altoona. (See Appendix G.)

No. 76. Quick Bend Test for Rail, by W. C. Cushing. (See Appendix H.)

No. 77. Report on Transverse Fissures, by Dr. P. H. Dudley. (See Appendix I.)

No. 78. Report on Extent of Use of Frictionless Rail and Results Obtained Therefrom. (See Appendix J.)

The paper on "Transverse Fissure Rails on the Pennsylvania Lines" gives the results of an investigation of sixty-one rails from one heat. The fissures were mostly of the "simple transverse" type. The carbon was somewhat high, but there was, in general, freedom from "segregation." The several mechanical tests showed about normal physical properties in the rail metal, except in the interior of head, where the metal was very low in ductility. The tests also showed that to detect this condition, the rails should be tested with the head in tension.

The paper on "Interior Fissure Rails on the Baltimore & Ohio Railroad" gives the results of an investigation of fifty rails from one heat. The fissures were of the "compound" type, in which the primary break is usually horizontal with a transverse branch issuing from it. The fissures worked out from threads of non-metallic inclusions in the interior of the head, which rendered the metal "crumbly" in a transverse direction.

The paper on "Transverse Fissure Rails on the Delaware, Lackawanna & Western Railroad" gives the results of an investigation of twenty-five rails from one heat.

The paper on "Tests of Splice Bars at Altoona" gives the results of an extensive investigation of several designs of rail joints and of the effect of heat treatment of the bars. This investigation showed that, although joints ordinarily had an elastic limit less than the continuous rail, still with suitable design of bar and heat treatment of the material, the joint has a higher elastic limit.

The paper on "Quick Bend Test for Rail" describes the hydraulic bending apparatus and gives the results of some comparisons with the drop test.

The "Report on Transverse Fissures" reviews the results of recent investigation and in particular presents a tabulation showing that transverse fissure failures have been much less numerous in rails from reheated blooms than in direct rolled rails.

The "Report on Frictionless Rail" gives the replies of seventeen railroads covering their experience with this type of rail on curves up to the close of 1918.

(4) MILL PRACTICE.

In order to decrease the pressure required to gag a rail, Dr. P. H. Dudley has been making experiments at several mills with the supports in the gag press increased from the usual spacing of 42 inches to spans up to 60 inches. Curves showing the relation between the distance between supports and the load required to produce permanent set are shown in Fig. 1. It will be noted that the load decreases as the span increases and consequently the local pressure of the bending die and the distortion of the metal at the point of pressure would decrease. Some experimental work has been done in gagging rails with the longer spans and we hope to have some developments to report at a later date.

We give below some notes of changes and improvements in mill practice. C. S. Churchill, Chairman of the Sub-Committee, made a report on the subject of Mill Practice, shown as Report No. 51, dated November, 1915.

The following paragraphs marked (*) were intended in Mr. Churchill's Report No. 51, and are complete except as to date of improvement:

Bethlehem Steel Company.

*Recarburizing now done by adding liquid iron to the furnace, instead of catching the carbon coming down which was the old practice.

*Reheating furnace installed to wash heat the hot blooms. (Operation was started about November, 1914.)

More details regarding the practice of reheating the blooms are as follows: The blooms remain in the furnace about one hour (57 minutes is the correct time) and the temperature of the bloom on entering the furnace is about 2030° F. and emerges 2360° F. Shrinkage allowance for all rail sections has been increased, as the rails finish hotter than when rolled direct.

Hot beds: Rails are carried out two at a time for the 105-lb. section, and not in groups of three or four as at other mills. The beds are carefully protected in the winter by enclosure of the entire building, which prevents gusts of cold air striking the cooling rails.

Stamping: All rails are stamped with the ingot number as well as the melt number and rail letter. -

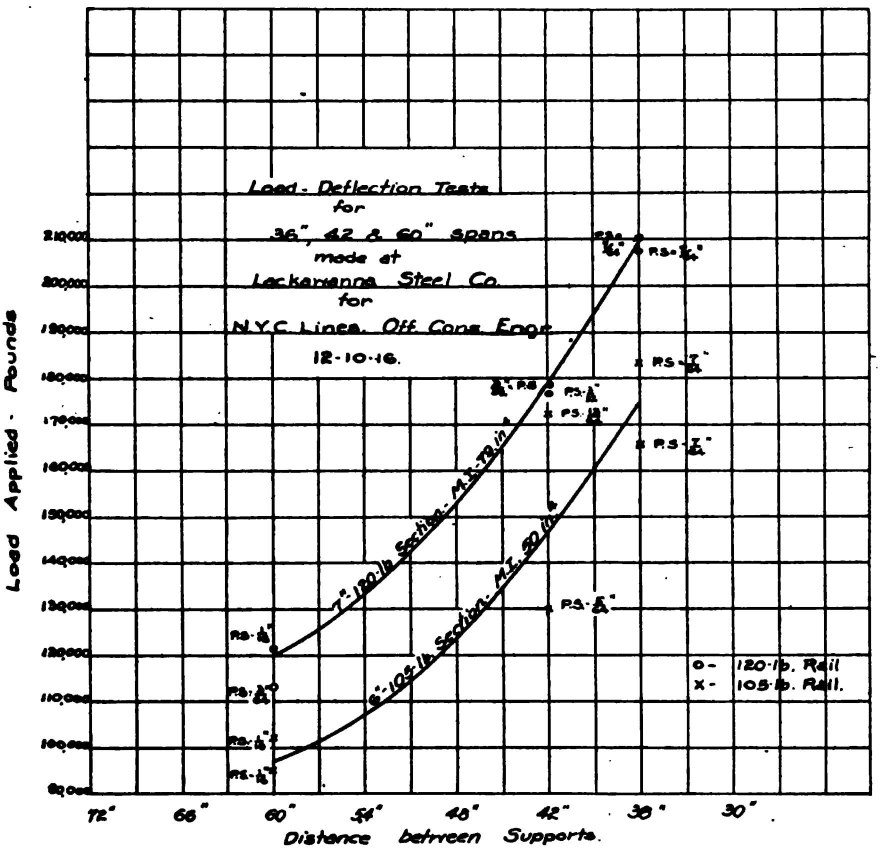


FIG. 1—THE LOAD REQUIRED TO BEND RAILS AS RELATED TO SPAN OF SUPPORTS.

Cambria Steel Company.

*Continuous bloom reheating furnace installed.

Carnegie Steel Company.

*Mill No. 2 placed in operation. The blooming passes of mill are used to roll the blooms for the old mill, No. 1.

The roughing, intermediate and finishing rolls in Mill No. 2 were placed in operation probably in 1914. The principal passes are constructed for diagonal rolling.

Rails from Mill No. 2 are gang sawed.

Straightening Presses: A new improved press is now in use, the chief features of which are as follows:

1. Die block is 18 in. wide, has a 4-in. flat at its center, and tapers 7 in. either side of this flat.
2. Stroke of press, 2 in.
3. Strokes per minute, 45.
4. Supports, 40 in. apart, inside to inside. General dimensions of supports, 4¼ in. wide, 12⅝ in. long and 2 in. thick.
5. Spring supported rollers are located 18 in. from the inside edge of the supports of the press. They are 9 in. in diameter, and the spring cylinder is 6 in. in diameter. The springs under the roller shafts are so adjusted as to cause the rail when first placed in the press to be about 3/32-in. above the level of the straightening press supports. When the application of the gag is made, the effect of the blow is first transmitted to the spring supported rollers, and this continues until the rail comes in contact with the supports of the press. This is in effect an actual lengthening of the distance between supports and considerably reduces the amount of work when the span of the rail between supports is 60 in. (The probable date of this change is February, 1918.)

Illinois Steel Company, Gary Works.

New Ingot Molds	*Compared to*	*Old Type*
22¾ in. square at bottom.		20 x 24 in. at bottom.
21½ in. square at top.		18¾ x 22¾ in. at top.
Fillets at bottom, 8 in.		Fillets at bottom, 2½ in.
Fillets at top, 7⅛ in.		Fillets at top, 3¼ in.
Height, 79 in.		Height, 78¼ in.

To roll ingots produced in these molds, it was necessary to reconstruct the tandem passes. The first three passes are "diamond" shape, as the ingot is turned so that the reduction of section is transmitted from these corners with their large radii fillets.

(These changes were made in 1917, and probably in March.)

A reduction in the number of rails containing head and base seams, also flaws, has followed these changes, and has much improved the general quality of the rail.

Straightening Presses: Two presses have been changed in detail to make the supports 60 in. apart. One other press has supports 54 in. apart. Others are to be changed in the future.

Lackawanna Steel Company.

Deseaming of the bottom of the rail bar started early in 1914.

Deseaming of the head and base started July 3, 1914.

Hot bed enclosures have been improved and all possible protection given to the rails, starting with the winter rollings of 1914-15.

Straightening Presses: First press with 60-in. supports installed or equipped November, 1916. Two other presses changed over to 60-in. supports during 1917 and 1918.

Pennsylvania Steel Company.

*Ingots formerly used were 18 x 24, finally adopted.

*The entire mill has been rebuilt including the soaking pits.

(5) RAIL JOINTS.

A standard method of testing rail joints is desirable to enable the results of different laboratories to be compared with each other, which cannot now ordinarily be done, due to differences in the details of conducting the tests. The Committee submits in Appendix B a method of testing rail joints with the recommendation that it be adopted and included in the Manual. This method proposes a span of four feet between supports, which is longer than has been used in most investigations of rail joints, but is done for the purpose of allowing the test to be made with a lighter load and thus allowing it to be made in a greater number of laboratories. This is also the span used in the hydraulic bend test of rails and in the drop test of sections of rail 111 pounds per yard and over.

The Altoona Laboratory of the Pennsylvania Railroad made some extensive tests of different joints and joint bars, the results of which are given in Report 75, Tests of Splice Bars at Altoona, Appendix G.

(6) MATERIAL FOR JOINT BARS.

Report 75 also gives the results of an investigation of the effect of heat treatment and the results showed that while ordinarily the rail joint has a lower elastic limit than the unbroken rail, joints made with bars of suitable designs and heat treated have elastic limits higher than the continuous rail.

(7) INTENSITY OF PRESSURE.

The Committee reports progress on this subject. The work described in the last annual report has been continued and we expect to report the additional findings at a later date.

(8) METHODS OF INSPECTION.

The Pennslyvania Railroad has continued work with the hydraulic or quick bend method of testing rails as described in Report 76, Quick Bend Test, Appendix H. This method seems to be preferable to the drop test, in that it gives more complete information, is quicker of operation and the breaks also are practically always normal tension breaks of the part in tension, which is frequently not the case in the drop test. For these reasons it has been included as an alternative method of testing rails in the proposed specifications for steel rails submitted with this report.

Another method that is being tried for the examination of the interior condition of rails is the process of deep etching of longitudinal sections, in strong acid. The Altoona Laboratory has examined some longitudinal slabs about ¼ inch thick cut from the interior of the head of transverse fissure rails, by keeping them for two hours in a hot mixture of hydrochloric and sulphuric acids. The Committee has modified this method by taking a slab consisting of the top part of the head as illustrated in Fig. 2. This slab is etched or pickled for 30 to 45 minutes in strong commercial hydrochloric or muriatic acid in a large porcelain dish and kept at a temperature of about 180 deg. F. The Committee

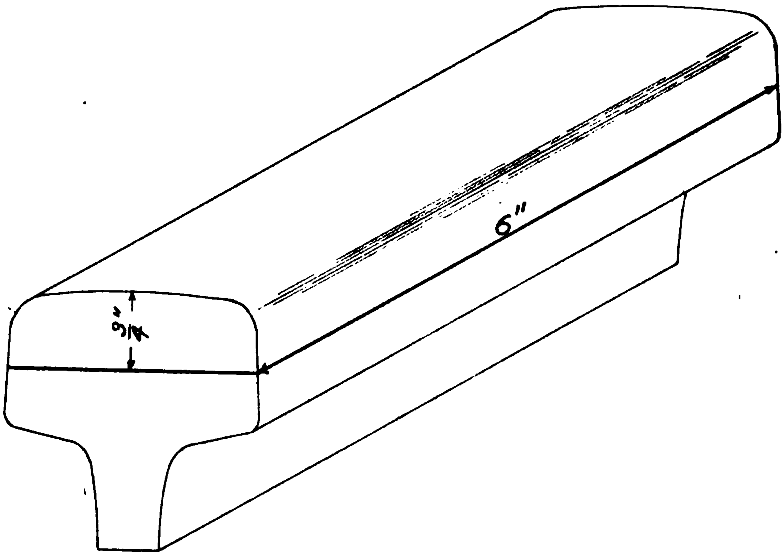


FIG. 2—SLAB OF RAIL HEAD FOR ETCHING.

expects to have some results from these examinations to report at a later date.

(9) FEDERAL AND STATE COMMISSION REQUIREMENTS.

The Committee has gathered some information on this subject but feels that under conditions as they are it is needless to continue work on the matter and asks to be relieved from further consideration of the subject.

RECOMMENDATIONS.

Your Committee submits the following recommendations:

1. That the method of testing rail joints submitted with this report be adopted by the Association and included in the Manual.

2. That the revised specifications for steel rails submitted with this report be printed in the Proceedings for consideration and discussion during the coming year.

RECOMMENDATIONS FOR FUTURE WORK.

The Committee recommends that subjects be assigned to it for 1919 as follows:

1. Make critical examination of the subject-matter in the Manual and submit definite recommendations for changes.
2. Report on rail failures and present statistics and conclusions as to causes and submit suggestions for improvements.
3. Continue special investigations of rail.
4. Present revised specifications for steel rails.
5. Present sections for rails heavier than 120 lbs. per yd.
6. Report on details of manufacture and mill practice as they affect quality of rail.
7. Report on material and design of joints and joint bars, and methods of treatment.
8. Report on rational relation between intensity of pressure due to wheel loads and resistance of rail steel to crushing and deformation.
9. Report on "Frictionless" rail.
10. Report on effect of age on the physical properties of rail steel.
11. Continue investigation and development of methods of inspection.

Respectfully submitted,

THE COMMITTEE ON RAIL.

Appendix A.

PROPOSED SPECIFICATIONS FOR CARBON STEEL RAILS.

INSPECTION.

Access to Works.

1. Inspectors representing the purchaser shall have free entry to the works of the manufacturer at all times while the contract is being executed, and shall have all reasonable facilities afforded them by the manufacturer to satisfy them that the rails have been made and loaded in accordance with the terms of the specifications.

Place for Tests.

2. All tests and inspections shall be made at the place of manufacture prior to shipment, and shall be so conducted as not to interfere unnecessarily with the operation of the mill.

MATERIAL.

Material.

3. The material shall be steel made by the Bessemer or Open-Hearth process as provided by the contract.

CHEMICAL REQUIREMENTS.

Chemical Composition.

4. The chemical composition of the steel, determined as prescribed in Section 6, shall be within the following limits:

CONSTITUENT ELEMENTS	BESSEMER PROCESS Limits Per Cent)		OPEN-HEARTH PROCESS (Limits Per Cent)		
	Weight in Pounds Per Yard		Weight in Pounds Per Yard		
	70-84	85 and Over	70-84	85-110	111 and Over
Carbon	0.40 to 0.50	0.45 to 0.55	0.53 to 0.66	0.62 to 0.75	0.67 to 0.80
Phosphorus, not to exceed	0.10	0.10	0.04	0.04	0.04
Manganese	0.80 to 1.10	0.80 to 1.10	0.70 to 1.00	0.70 to 1.00	0 70 to 1 00
Silicon, not less than	0.10	0.10	0.10	0.10	0.10

Average Carbon.

5. It is desired that the percentage of carbon in an entire order of rails shall average as high as the mean percentage between the upper and lower limits specified.

Analyses.

6. In order to ascertain whether the chemical composition is in accordance with the requirements, analyses shall furnished as follows:

A. Bessemer Process.

The manufactuer shall furnish to the inspector, daily, carbon determination for each heat before the rails are shipped, and two chemical analyses every twenty-four hours repre-

senting the average of the elements, carbon, manganese, silicon, phosphorus and sulphur contained in the steel, one for each day and night turn, respectively. These analyses shall be made on drillings taken from the ladle test ingot not less than ⅛ inch beneath the surface.

B. Open-Hearth Process.

(a) Finished Rail Analysis. An analysis shall be made for the elements, carbon, manganese, silicon, phosphorus and sulphur, of a piece of rail representing each heat. The drillings for these analyses shall be taken from a piece of the finished rail bar adjacent to a drop test specimen, longitudinally of the rail with a one-half inch drill, close to an upper corner of the head.

(b) Ladle Analysis. For the information of the Inspector, the manufacturer shall furnish a chemical analysis of the elements, carbon, manganese, silicon, phosphorus and sulphur, for each heat. These analyses shall be made on drillings taken from the ladle test ingot not less than one-eighth inch beneath the surface.

C. Check Analyses.

On request of the inspector, the manufacturer shall furnish a portion of the ladle test ingot for check analyses.

PHYSICAL REQUIREMENTS.

Physical Qualities.

7. Tests shall be made to determine:

(a) Ductility or toughness as opposed to brittleness.
(b) Soundness.

Method of Testing.

8. The physical qualities shall be determined by:

(a) The Drop Test, or
(b) The Quick Bend Test, if made a part of the contract.

Drop Testing Machine.

9. The drop testing machine used shall be the standard of the American Railway Engineering Association, the essential points of which are:

(a) The tup shall weigh 2,000 lbs., and have a striking face with a radius of five inches.

(b) The anvil block shall weigh 20,000 lbs., and be supported on springs.

(c) The supports for the test pieces shall be a part of, and firmly secured to, the anvil; their bearing surface shall have a radius of five inches..

(d) The spacing of the supports between centres shall be:
3 feet for rails weighing 110 lbs. or less per yard,
4 feet for rails weighing from 111 to 140 lbs. per yard, inclusive.

Machine for Quick Bend Test.

10. The Quick Bend Test shall be made with a hydraulic press of not less than 350 tons capacity, some of the details of which are as follows:

(a) The foundation for the supports for the test specimens shall be adequate to sustain rigidly the total load applied by the press.

(b) The supports shall be solid flat bearing surfaces, with vertical faces 48 inches apart, with the inner edges rounded to a ⅛ inch radius.

(c) The head of the ram shall have a bearing face with a radius of five inches.

(d) The speed of the ram shall approximate 13 feet per minute when allowed free travel.

(e) A hydraulic indicator shall be connected with the press so that the pressure on the head of the ram is registered by the pen arm on a vertical scale, and the distance rotated by the cylinder shall be proportional to the travel of the ram head.

Test Specimens.

11. (a) Test specimens shall be one to two feet longer than the span between supports in the testing machine.

(b) Test specimens shall be cut from the crop of the top rail of the ingot, and marked on the center line of the top surface of the head with gage marks on inch apart for three inches each side of the center of the specimen, for measuring the ductility of the metal.

(c) Where it is necessary to test rails lower than the first rail, the bottom of the first rail, in lieu of the top of the second rail, and the bottom of the second rail, in lieu of the top of the third rail, will be accepted, if preferred by the manufacturer.

(d) The temperature of the test specimen shall be between 60 and 100 degree Fahrenheit.

(e) Unless otherwise instructed by purchaser, the test specimens shall be tested with head in tension and with the center punch marks midway between supports.

Height of Drop.

12. The test piece shall be subjected to impact of the tup falling free from the following heights:

For 70 to 79 lb. rail, incl.	16 feet.
For 80 to 90 lb. rail, incl.	17 feet.
For 91 to 110 lb. rail, incl.	18 feet.
For 111 to 140 lb. rail, incl.	20 feet.

Elongation.

13. Under these impacts the rail under one or more blows shall show at least 8 per cent. elongation for one inch of the six inch scale, marked as described in Section 11 (b).

Exhausted Ductility Test.

14. A sufficient number of blows shall be given to determine the

complete elongation of the test piece of at least every fifth heat of Bessemer steel, and of one out of every three test piecs of a heat of open-hearth steel.

Permanent Set.

15. For each specimen, a record shall be made of the permanent set after each blow under the drop test.

Test to Destruction.

16. The test pieces which do not break under the first or subsequent blows shall be nicked and broken, to determine whether the interior metal is sound. The words "interior defect", used below, shall be interpreted to mean seams, laminations, cavities or interposed foreign matter made visible by the destruction tests, the saws or the drills.

Bessemer Process Physical Tests.

17. One piece shall be tested from each heat of Bessemer steel.

(a) If the test piece shows the required elongation (Section 13), all of the rails of the heat shall be accepted, provided that the test piece when broken does not show interior defect.

(b) If the test piece does not show the required elongation (Section 13), or if when broken shows interior defect, all of the top rails from that heat shall be rejected.

(c) A second test shall then be made of a test piece selected by the inspector from the top end of any second rail of the same heat, preferably of the same ingot. If the test piece shows the required elongation (Section 13), all of the remainder of the rails of the heat shall be accepted, provided that the test piece when broken does not show interior defect.

(d) If the test piece does not show the required elongation (Section 13), or if when broken shows interior defect, all of the second rails from that heat shall be rejected.

(e) A third test shall then be made of a test piece selected by the inspector from the top end of any third rail of the same heat, preferably of the same ingot. If the test piece shows the required elongation (Section 13), all of the remainder of the rails of the heat shall be accepted, provided that the test piece when broken does not show interior defect.

(f) If the test piece does not show the required elongation (Section 13), or if when broken shows interior defect, all of the remainder of the rails from that heat shall be rejected.

Open-Hearth Process Physical Tests.

18. Test pieces shall be selected from the second, middle and last full ingot of each open-hearth heat.

(a) If all of these test pieces show the required elongation (Section 13), all of the rails of the heat shall be accepted, provided that no test piece, when broken, shows interior defect.

(b) If any test piece does not show the required elongation

(Section 13), or, if when broken shows interior defect, all of the top rails from that heat shall be rejected.

(c) Second tests shall then be made from three test pieces selected by the inspector from the top end of any second rails of the same heat, preferably of the same ingots. If all these test pieces show the required elongation (Section 13), all of the remainder of the rails of the heat shall be accepted, provided that no test piece, when broken, shows interior defect.

(d) If any test piece does not show the required elongation (Section 13) or, if when broken, shows interior defect, all of the second rails of the heat shall be rejected.

(e) Third tests shall then be made from three test pieces selected by the inspector from the top end of any third rails of the same heat, preferably of the same ingots. If all these test pieces show the required elongation (Section 13), all of the remainder of the rails of the heat shall be accepted, provided that no test piece, when broken, shall show interior defect.

(f) If any test piece does not show the required elongation (Section 13), or, if when broken shows interior defect, all of the remainder of the rails from that heat shall be rejected.

No. 1 Rails.

19. "No. 1 Rails" shall be free from injurious defects and flaws of all kinds.

No. 2 Rails.

20. Rails which vary from the specification in a manner which does not impair their soundness and strength will be accepted as "No. 2 Rails." The rails to be so accepted are as follows:

(a) Rails arriving at the straightening presses with sharp kinks or greater camber than that indicated by a middle ordinate of 4 inches in 33 feet for the thick base sections, and 5 inches for the thin base sections.

(b) Rails which do not contain surface imperfections in such number or of such character as will, in the judgment of the inspector, render them unfit for recognized No. 2 uses.

Rails accepted as No. 2 rails shall have the ends painted white, and shall have two prick punch marks on the side of the web near the heat number, near the end of the rail, so placed as not to be covered by the joint bars.

No. 2 Rails to the extent of 5 per cent. of the whole order will be accepted.

Details of Manufacture.

Quality of Manufacture.

21. The entire process of manufacture shall be in accordance with the best current state of the art.

Bled Ingots.

22. Bled ingots, from the center of which the liquid steel has been permitted to escape, shall not be used.

Discard.

23. There shall be sheared from the end of the bloom, formed from the top of the ingot, sufficient metal to secure sound rails.

Lengths.

24. The standard length of rails shall be 33 geet, at a temperature of 60 degrees Fahrenheit. Ten per cent. of the entire order will be accepted in shorter lengths varying by 1 foot from 32 to 25 feet. A variation of ¼ inch from the specified lengths will be allowed. No. 1 rails less than 33 feet shall be painted green on both ends.

Deoxidation.

25. The steel must be well deoxidized and the waste products eliminated before the ingots are teemed, and thus prevent minute portions of the deoxidation products from becoming entrained in the setting metal. Time is required for the deoxidation products and impurities to rise after the steel is tapped into the ladle.

Stool Cutting.

26. Care shall be taken in teeming the ingots to prevent cutting out of the cast iron of the stools of ingot molds by the falling stream of hot metal from the ladle, and thus avoid a frequent cause of carbon streaks found in the finished rail.

Mold Spattering.

27. Spattering the interior sides of the molds in pricking the heats or melts and teeming the ingots must be avoided as much as possible.

Stopper Defects.

28. Excessive use of material thrown into the teeming ladle to set the stopper must be avoided.

Aluminum.

29. The steel must be made to set quiet by the chemical composition in the molds without the addition of aluminum, either in the ladle or molds.

Time for Ingot Setting.

30. Time must be allowed for the tops of the ingots to set without spraying with water.

Ingots Vertical.

31. Ingots shall be kept in a vertical position on the ingot cars and in the reheating furnaces until their heat is equalized ready to be rolled.

Ingot Shrinkage.

32. The ingots should be stripped as soon as the metal caps over on top; sent to the scales to be weighed and then sent to the reheating furnace to be charged promptly. This avoids cooling of the interior metal and thus checks the shrinkage, which may be large, depending upon the

volume, chemical composition and temperature of ingot at time it is charged. The interior shrinkage can be confined to 0.05 and 0.1 per cent. per cubic foot of the metal, so that it is eliminated in the usual discard of the bloom, and helps to prevent piped rail due to cold ingots.

Reheating the Blooms.

33. The mill practice of blooming the ingots and then charging the blooms into reheating furnaces for a wash heat before rolling the rails has checked the development of internal transverse fissures. They are decidedly more numerous in the product of mills that roll the rails direct from the ingots.

One mill since original construction and operation has built furnaces to reheat the blooms, and another mill has arranged to build a furnace to reheat the blooms after direct rolling for many years. There are six mills in the United States and Canada that reheat the blooms, and eight that roll direct.

(This paragraph is inserted as information derived from the statistics of rail failures.)

Blooming and Rolling.

34. Blooming the ingots and rolling the blooms into finished rails must all be done when the ranges of temperature for the ingots, blooms and rails are suitable for the metal to be cambered and then cooled so that the transformations and recalescence will be complete for the desired steel.

Rail Shrinkage.

35. The number of passes and speed of train shall be so regulated that on leaving the rolls at the final pass, the temperature of the rail will not exceed that which requires a shrinkage allowance at the hot saws, for a rail 33 feet in length and of 100 lb. section, of six and three-fourths inches and one-eighth inch less for each ten lbs. decrease in section or ⅛ inch more for each ten pounds increase in section.

Artificial Cooling.

36. The bars shall not be held for the purpose of reducing their temperature, nor shall any artificial means of cooling them be used after they leave the finishing pass.

Section.

37. The section of rails shall conform as accurately as possible to the template furnished by the Railroad Company. A variation in height of one-sixty-fourth inch less or one-thirty-second inch greater than the specified height and one-sixteenth inch in width of flange, will be permitted; but no variation shall be allowed in the dimensions affecting the fit of the joint bars.

Weight.

38. The weight of the rails specified in the order shall be maintained as nearly as possible, after complying with the preceding section. A vari-

ation of one-half of 1 per cent. from the calculated weight of section, as applied to an entire order, will be allowed.

Hot Bed Work and Straightening.

39. (a) Care must be taken in cambering the rails and with the hot-bed work so that rails will cool with a small but uniform sweep, and therefore gagging under the presses will be reduced to a minimum.

(b) The hot rails from the saws on their way to the "hot-beds" should be spaced to allow the recalescence of the head to follow the base without being locked or blocked by adjacent rails on either side.

(c) Rails while on the cooling beds shall be protected from snow, water and excessive gusts of cold wind.

(d) When delivered to the straightening presses rails shall not vary in any direction from a straight line throughout their entire length more than 4 inches for the "RE" and "RA" thick base sections, and not more than 5 inches for "ASCE" sections.

(e) The supports for rails in the straightening presses shall have flat surfaces and be out of wind, and shall be spaced not less than 42 inches. The application of the gag shall be central between supports, and the overhang of either end of the rail during straightening should be supported.

(f) Rails heard to snap while being straightened shall be at once rejected.

Drilling.

40. Circular holes for joint bolts shall be drilled to conform to the drawing and dimensions furnished by the Railroad Company.

Finishing.

41. (a) All rails shall be smooth on the heads, straight in line and surface, and without any twists, waves or kinks. They shall be sawed square at the ends, a variation of not more than one-thirty-second inch being allowed; and burrs shall be carefully removed.

(b) Rails improperly drilled or straightened, or from which the burrs have not been removed, shall be rejected, but may be accepted after being properly finished.

(c) When any finished rail shows interior defects at either end or in any drilled hole, the entire rail shall be rejected.

Branding.

42. Rails shall be branded for indentification in the following manner:

> (a) The name of the manufacturer, the month and year of manufacture, and the weight and type of section of rail shall be rolled in raised letters and figures on one side of the web. The type shall be marked by letters which signify the name by which it is known, as for example:

Sections of American Society of Civil Engineers........A.S.C.E.
Sections of American Railway Association......R.A. -A., R.A.-B.
Sections of American Railway Engineering Association......R.E.

(b) The heat and ingot number and letter indicating the portion of the ingot from which the rail was made shall be plainly stamped on the web of each rail where it will not be covered by the joint bars. The top rails shall be lettered "A" and the succeeding ones "B", "C", "D", etc., consecutively; but in case of a top discard of from 20 to 35 per cent., the letter "A" will be omitted, the top rail becoming "B." If the top discard be greater than 35 per cent., the letter "B" shall be omitted, the top rail becoming "C".

(c) Open-hearth rails shall be branded or stamped "O-H" in addition to other marks.

(d) Bessemer rails shall be branded or stamped "BES", in addition to the other marks.

(e) All markings of rails shall be done so effectively that the marks may be read as long as the rails are in service.

Separate Classes.

43. All classes of rails shall be kept separate from each other.

Loading.

44. Rails shall be carefully handled and loaded in such manner as not to injure them.

Payment.

45. Rails accepted will be paid for according to actual weight.

Appendix B.

PROPOSED STANDARD TEST FOR RAIL JOINTS.

In order that comparison of results of different types of joint bars may be made, the uniform method of procedure for laboratory test shall be as follows:

General Assembly.

Complete rail joints, full bolted, shall be used. Before joints are bolted the loose scale shall be removed from the contact surfaces of rails and joint bars so that there may be clean, dry surfaces for surface contact. Rail joints shall be then subjected to tests that will show the strength and deflection of the joint under transverse load with head up and also with head down.

The results are to be compared with a test of a continuous rail of the same span for determination of rail joint efficiency and rigidity.

The joints are to be bolted with heat treated bolts, or if other bolts are used, the quality and kind of bolt shall be stated.

The rail used for test of joints shall be cut from the same piece of rail as rail for continuous span. Rails used for test pieces shall be preferably from the same rail or at least from the same heat of rails. New rails and joint bars shall be used for test.

Quality of Material.

Material for both rail and joint bars shall be subjected to standard tension tests, to hardness tests, to chemical analyses and, if heat treated material, to microscopic examination.

Measurements to be recorded for joint bars of the area sketch of section, moment of inertia, length, weight, location of bolt holes, camber if any.

Measurements of rail section include area sketch of section, moment of inertia, weight per yard, location and size of bolt holes.

Joints are to be bolted up so that there shall be a space of 3/8 of an inch between the ends of the adjoining rails. Bolts are to be applied so that they shall not be in contact with the sides of the bolt holes through the rails. If necessary ends of rails to be faced off to give required spacing and bolt clearance.

The supports shall be solid, flat bearing surfaces with vertical faces 48 inches apart, with the inner edges rounded off to 1/8 of an inch radius. The load to be applied midway between the supports by a block, having a radius of 16½ inches, and a width not less than the width of the base of the rail.

Loading.

An initial load of 3,000 pounds shall be made at which load the deflectometer shall be set at zero. Uniform increments of load of such magnitude shall then be applied to accurately define the elastic limit.

Maximum deflection and set to be determined for each increment of loading. Deflections and permanent sets to be measured to one-thousandths of an inch. Loading to continue until adjacent rail ends meet.

Note is to be made of readings of the load at which the joint bars or rails commence to scale.

Number of Tests.

Three concordant tests shall be made, and results shall be recorded in detail. Abnormal tests to be discarded.

Efficiency.

The efficiency of a rail joint is expressed as the ratio of the elastic limit in pounds of the rail joint divided by the elastic limit of the continuous rail; this efficiency to be given first with head up, second with head down, using data to correspond to conditions imposed. Rail joint efficiencies shall be expressed in per cent.

Rigidity.

The rigidity of a joint is a comparison of the deflections of the rail and the joint under the load that develops the elastic limit of the joint. It is the ratio expressed in per cent., of the deflection of the rail to the deflection of the joint at this loading; that is, the deflection of the rail divided by the deflection of the joint at the elastic limit of the joint.

The rigidity shall be expressed for the two conditions of test, with head up and with head down.

Appendix C.

TRANSVERSE FISSURE RAILS ON PENNSYLVANIA LINES—HEAT 31531

By M. H. Wickhorst, Engineer of Tests, Rail Committee.

This report gives the results of tests of a heat of rails in which five rails failed, due to transverse fissures and which was then removed from service. The rails were on the P. F. W. & C. Branch of the Pennsylvania Lines West of Pittsburgh. Through the kindness of the officials of the Pennsylvania System, the rails were sent to the Altoona Laboratory and investigated as described below. There were 61 rails in this investigation, which were numbered from 1 to 61 inclusive and were located in the track as shown in Table 1, which also gives per cents of grade.

Table 1—Locations and Grades.

Numbers	Near Mile-Post	Traffic	Grade
1 to 5	203	West Bound	—.014
6 to 10	274	East Bound	+.14
11	286	West Bound	+.06
12 and 13	290	West Bound	—.03
14 to 16	290	West Bound	+.03
17 to 19	291	West Bound	—.17
20	295	West Bound	+ 18
21 to 28	300	West Bound	+.05
29 to 31	300	West Bound	.00
32 to 36	335	West Bound	—.38
37	336	West Bound	— 25
38 to 41	379	East Bound	+.33
42	380	East Bound	—.13
43 to 48	381	East Bound	— 17
49 to 54	381-2	East Bound	+.38
55 to 61	393	West Bound	—.37

The rails were open-hearth steel rolled by the Gary Works of the Illinois Steel Company on December 7, 1912, heat number 31531, and were of the 100 lb. P. S. section. The heat made 24 ingots and 144 rails, of which 61 rails were rounded up for this investigation. The heat was originally inspected under the specifications of the Pennsylvania Lines West of Pittsburgh, dated January 10, 1912, which required a drop test from a height of 15 ft. The inspection record showed that test pieces from the top of the second and twelfth ingots, tested presumably with base in tension, broke on the first blow, thereby rejecting the A rails of the heat. The re-tests on the B rails met the requirements of the specification, each showing 5 per cent elongation in 2 inches, and the balance of the heat was accepted.

Report No. 71, March, 1918.

TABLE 2—RESULTS OF DROP TESTS.

Rail Letter	Track Grade %	Rail Number	Number of Breaks Total	Number of Breaks With fissures
B	+.33	39	8	5
"	+.03	14	12	4
"	+.03	16	5	-
"	.00	31	8	4
"	-.014	5	3	-
"	-.03	13	10	1
"	-.17	44	-	-
"	-.25	37	2	-
"	-.37	57	4	-
"	-.38	33	12	4
Total		10	64	18
Per rail			6.4	1.80
C	+.38	50	6	-
"	+.33	40	4	-
"	+.12	20	10	2
"	+.05	21	12	4
"	.00	30	3	1
"	-.13	42	4	-
"	-.17	17	7	-
"	-.17	47	5	-
Total		8	51	7
Per rail			6.4	0.88
D	+.38	53	6	-
"	+.33	41	4	-
"	+.14	6	-	-
"	+.14	7	8	-
"	+.06	11	8	-
"	+.05	22	1	-
"	+.05	23	5	1
"	+.03	16	2	-
"	-.014	4	2	-
"	-.17	18	-	-
"	-.17	43	8	-
"	-.17	46	2	-
"	-.17	48	2	-
"	-.37	58	8	-
"	-.37	60	5	-
Total		15	61	1
Per rail			4.1	.07
E	+.03	15	8	-
"	-.014	2	9	-
"	-.014	3	3	-
"	-.03	12	-	-
"	-.05	24	7	-
"	-.17	45	6	-
"	-.37	56	8	3
Total		7	41	3
Per rail			5.9	0.38
F.	+.38	49	12	2
"	+.38	51	5	-
"	+.38	52	11	1
"	+.38	54	12	7
"	+.33	38	12	12
"	+.14	8	10	-
"	+.14	9	10	-
"	+.14	10	4	-
"	+.05	26	11	3
"	+.05	27	10	-
"	+.05	28	5	-
"	.00	29	-	-
"	-.014	1	12	5
"	-.17	19	8	-
"	-.37	55	12	5
"	-.37	59	11	3
"	-.37	61	12	1
"	-.38	32	10	1
"	-.38	34	4	-
"	-.38	35	11	-
"	-.38	36	3	-
Total		21	185	40
Per rail			8.8	1.90
All rails		61	402	69

The rails were laid from December, 1912, to March, 1913, and removed during March to May, 1917. They were most of them in service a little over four years, and in that time the rail maintained the shape of its section well with but little wear. A section six ft. long was cut from the middle of each rail by means of an oxygen-acetylene torch and this part used for chemical analyses, tensile tests, etchings and quick bend tests in the hydraulic bender. The remaining two pieces of each rail were subjected to drop tests to disclose any fissures in them.

Drop Tests.

The long pieces of rail were subjected to a drop test every 18 inches throughout their lengths on supports 36 inches apart, using a 1640 lb. tup from a height of six ft., the rails being supported head down. The results of these tests are given in Table 2, which shows for each rail the total number of breaks and the number of breaks with fissures, grouped by rail letter or ingot position of the rail and the groups sorted by the per cent of grade of the track on which the rails were laid. For convenience the group results are copied in Table 3.

Table 3—Summary of Drop Tests.

Ingot Position	Number of Rails		Average per Rail	
	Total	With Fissures	Breaks	Fissures
B	10	5	6.4	1.80
C	8	3	6.4	.88
D	15	1	4.1	.07
E	7	1	5.9	.31
F	21	10	8.8	1.90
All	61	20		

It will be noted that numerous breakages occurred in all ingot positions. Numerous fissures also were found in the B, C. and F rails, but only a few in the D and E rails. The A rails do not occur in this list as they were rejected in the original inspection by the drop test.

The fractures which showed transverse fissures are illustrated in Figs. 1, 2, 3 and 4, arranged by ingot position and rail letter. These include those found in the drop test and the quick bend test described later. It will be noted that most of the fissures were of the simple transverse type with the bright polished part of the fissure in various stages of development surrounding a granular nucleus. There were also some compound fissures in which the transverse part is seen to have developed from a horizontal fissure or a vertical split in the head. A study of the simple transverse fissures suggests the thought that the nucleus formed as a sudden break and the polished part then formed as a gradual growth, the nucleus grains remaining far enough apart to prevent the polishing seen in the surrounding part of the fissure. Fig. 5 shows some fractures with

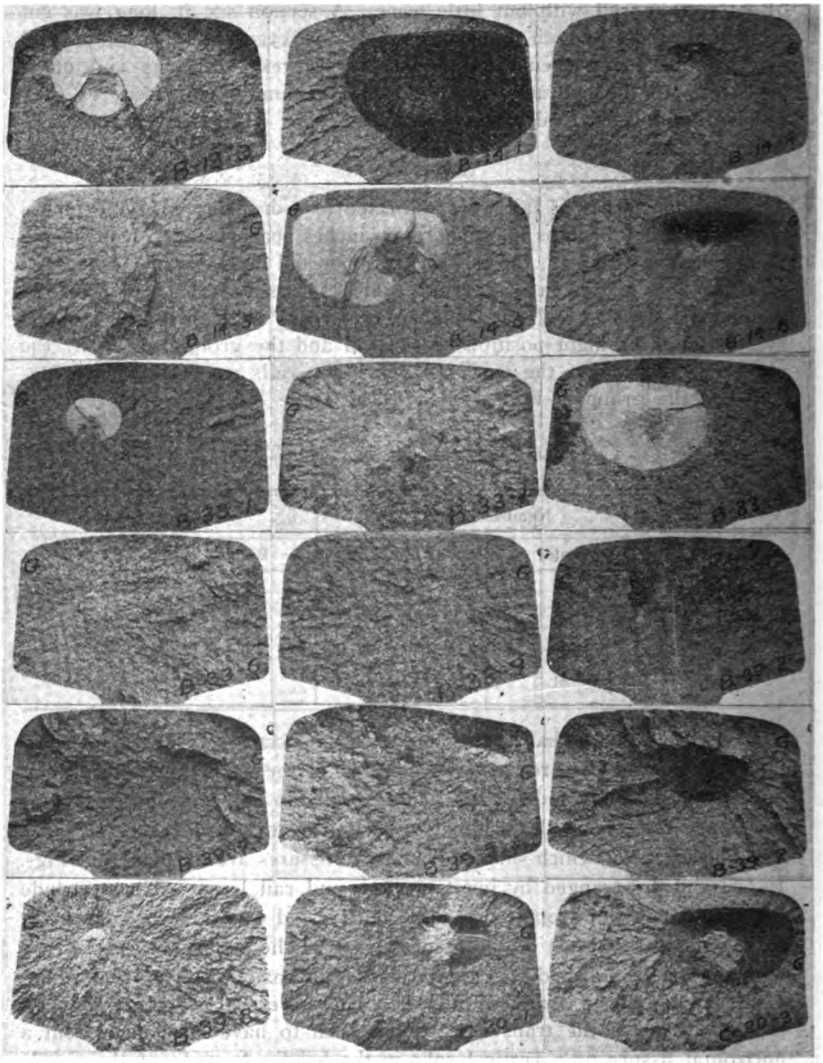


FIG. 1—FISSURES FOUND IN DROP TEST IN B AND C RAILS.

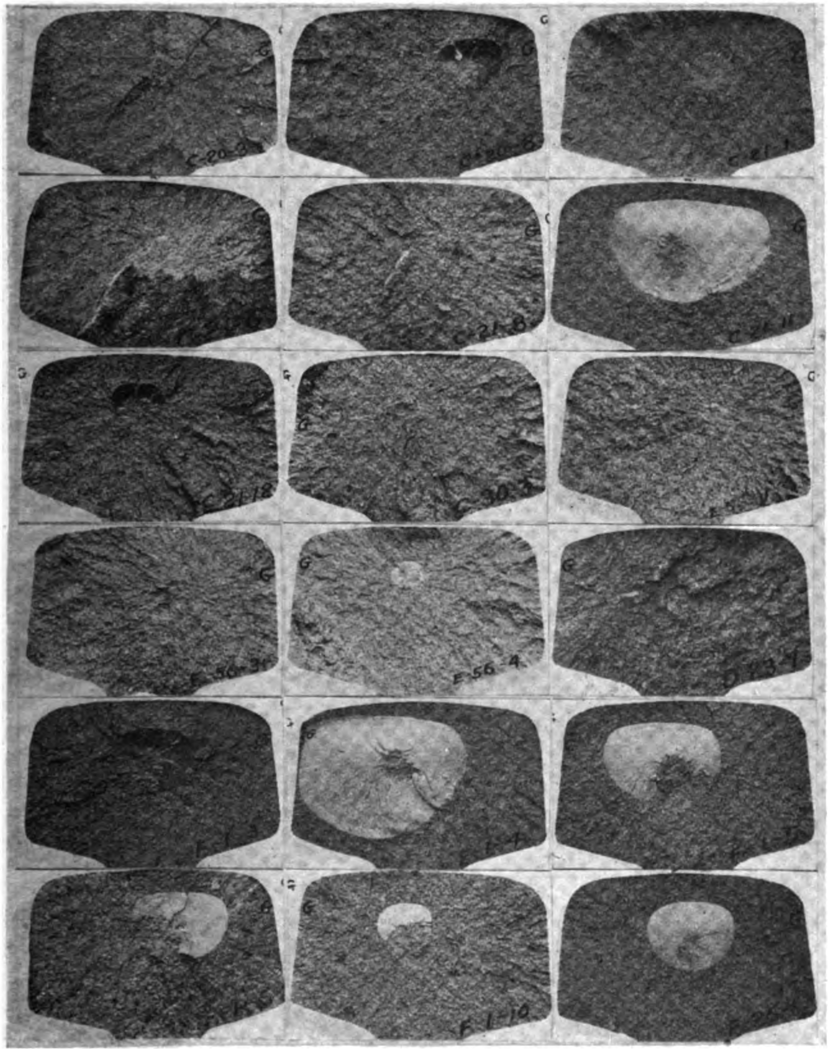


FIG. 2—FISSURES FOUND IN DROP TESTS IN C, D, E AND F RAILS

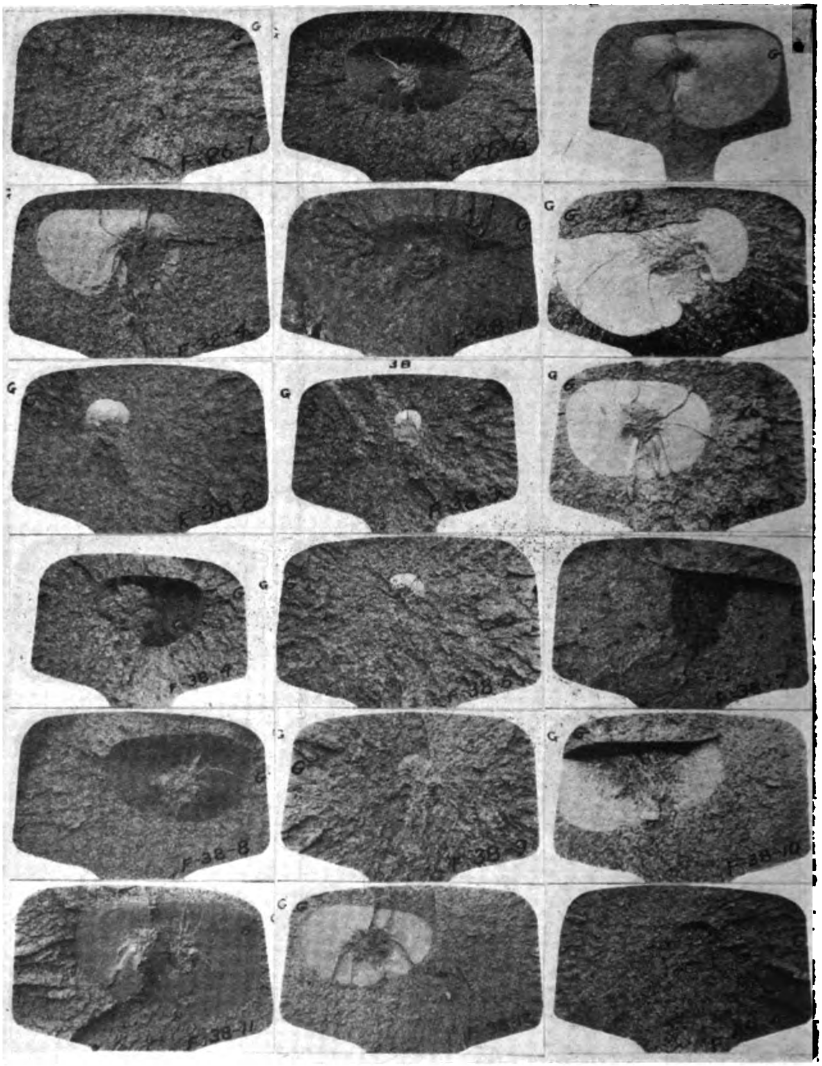


FIG. 3—FISSURES FOUND IN DROP TEST IN F RAILS.

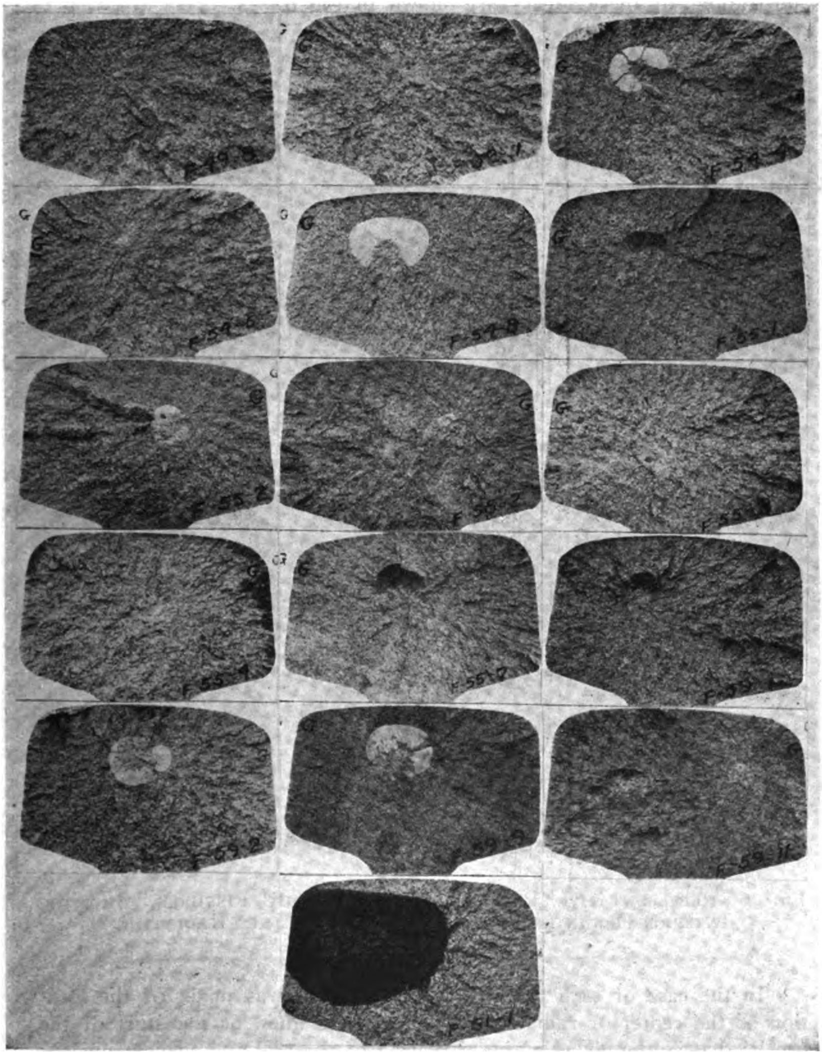


FIG. 4—FISSURES FOUND IN DROP TEST IN F RAILS.

vertical splits. In most of the plain breaks which showed no fissures or splits, the fracture lines radiated from a point in the interior of the head, showing the break to have started at the inside, and a few representative illustrations of these breaks are shown in Fig 6.

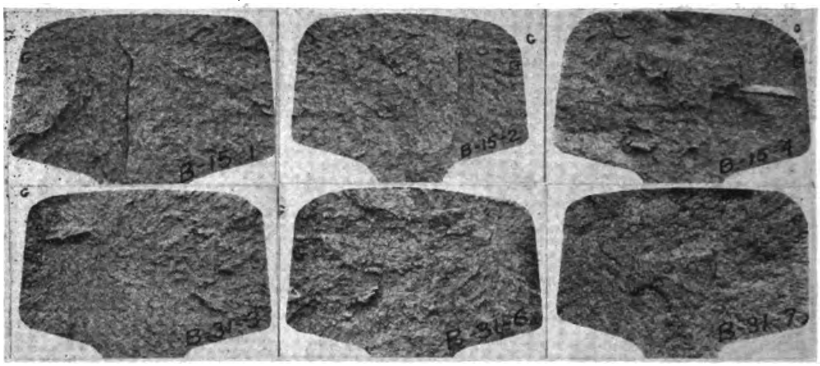


Fig. 5—Fractures with Vertical Splits.

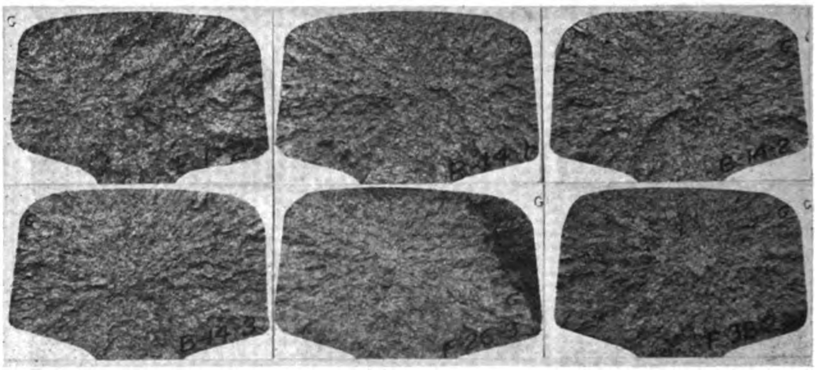
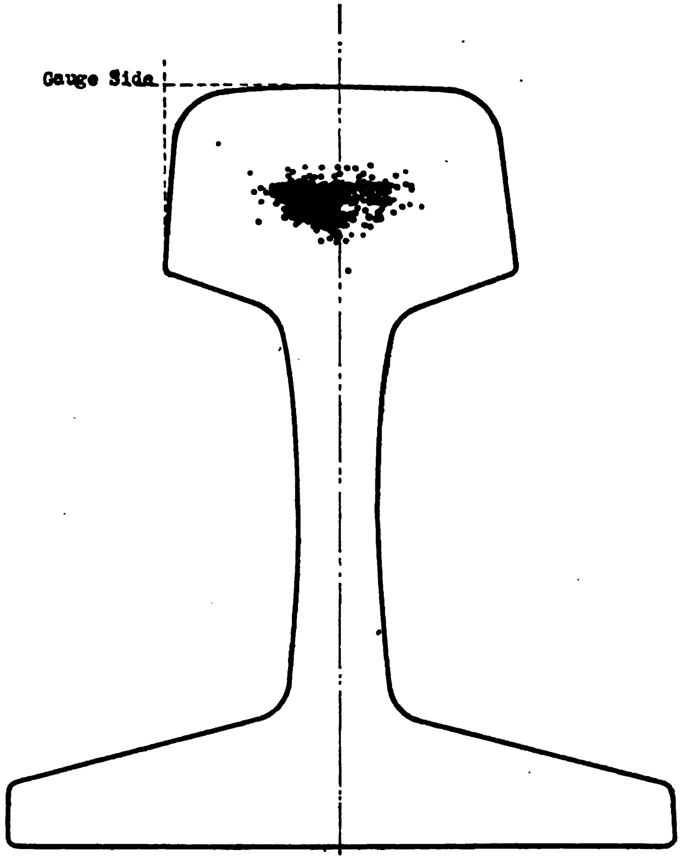


Fig. 6—Representative Plain Breaks Without Fissures, Showing Interior Origin of Breaks by Fracture Lines Radiating from Interior.

In the case of each fracture a measurement was made of the location of the center of radiation of the fracture lines, or the start of the break; that is, the distance was measured of the real or apparent nucleus from the top of the head and from the gage side. The results of these measurements are shown in two composite diagrams, Figs. 7 and 8. The former shows the centers of radiation of 345 breaks without fissures and the other shows the centers of the nuclei of 79 fissures. It will be noted

that the nuclei of the fissures were mostly on the gage side and somewhat above the center of the head of the rail, averaging about ⅝ in. from the top of the head and about 9/32 in. from the center line. The origins of the plain breaks were close to the center of the head, averaging about ⅞ in. from the top of the head and about ⅛ in. from the center line toward the gage side. When a rail is bent with the head down, all parts



Number of Breaks - 345.

FIG. 7—CENTERS OF RADIATION OF PLAIN BREAKS WITHOUT FISSURES.

of the head are put in tension and the greatest stretch occurs at the top of the head with successively less stretch as we go to the web. The breakage in these cases was determined by the ductility of the interior metal, the elongation of which, with the height of drop used, would be estimated to have been less than one per cent.

Chemical Analysis.

Two samples were taken for analysis from near the middle of each rail, one from the O position (outside), near an upper corner of the head, and the other from the M position (middle), from the interior of the head near the web, as shown in Fig. 9. On each sample determina-

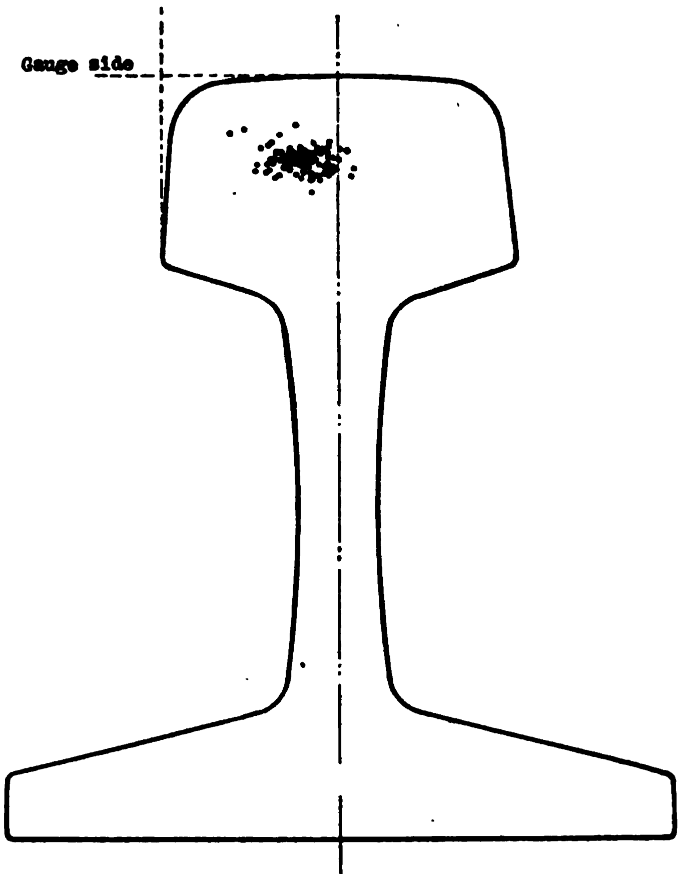


Fig. 8—Center of Nuclei of Fissures.

tions were made of the carbon, manganese, phosphorus, silicon and sulphur and the results are given in Table 4, grouped by ingot positions of the rails and the presence or absence of fissures as disclosed by the drop or quick bend tests.

TABLE 4—ANALYSES OF RAILS.

Fissures Found	Rail Letter	Rail No.	O Position C	O Position Mn	O Position P	O Position Si	O Position S	M Position C	M Position Mn	M Position P	M Position Si	M Position S	Carb. Seg.%
Yes	B	13	.887	.75	.028	.110	.031	.822	.74	.025	.085	.030	-7.3
"	"	14	.871	.71	.028	.098	.034	.796	.71	.024	.109	.032	-8.6
"	"	31	.858	.75	.024	.105	.030	.938	.77	.025	.099	.034	9.3
"	"	33	.864	.78	.024	.105	.035	.843	.77	.023	.103	.033	-2.4
"	"	39	.860	.76	.025	.098	.032	.955	.78	.029	.104	.038	11.1
	Average		.868	.75	.026	.103	.032	.871	.75	.025	.100	.033	0.3
No	B	5	.849	.79	.025	.126	.033	.958	.80	.030	.128	.041	12.8
"	"	15	.863	.78	.025	.104	.034	.950	.79	.031	.103	.038	10.1
"	"	37	.882	.77	.027	.109	.032	.827	.76	.024	.104	.031	-6.2
"	"	44	.837	.77	.024	.092	.032	.951	.79	.031	.091	.038	13.6
"	"	57	.866	.75	.031	.094	.037	.929	.73	.035	.094	.042	7.0
	Average		.859	.77	.026	.105	.033	.923	.77	.030	.104	.038	7.4
Average all B rails			.864	.76	.026	.104	.033	.897	.76	.028	.102	.036	3.8
Yes	C	20	.891	.74	.029	.091	.035	.818	.77	.026	.083	.035	-8.2
"	"	21	.869	.74	.027	.115	.036	.807	.75	.024	.111	.031	-7.1
"	"	30	.900	.77	.027	.097	.035	.907	.77	.028	.105	.035	.8
	Average		.887	.75	.028	.101	.035	.844	.76	.026	.100	.034	-4.9
No	C	17	.891	.73	.029	.084	.037	.891	.74	.032	.093	.039	0.0
"	"	40	.891	.78	.028	.097	.035	.931	.79	.029	.100	.035	4.5
"	"	42	.891	.77	.028	.093	.036	.945	.78	.031	.106	.038	6.1
"	"	47	.855	.77	.029	.106	.036	.826	.77	.028	.091	.036	3.4
"	"	50	.882	.73	.032	.086	.038	.873	.76	.031	.094	.038	-1.0
	Average		.882	.76	.029	.093	.036	.893	.77	.030	.097	.037	1.2
Average all C rails			.884	.75	.029	.096	.036	.875	.77	.029	.098	.036	-1.0
Yes	D	23	.818	.75	.027	.104	.029	.983	.80	.040	.098	.051	20.2
No	D	4	.881	.77	.027	.106	.033	.863	.77	.025	.110	.034	-2.0
"	"	6	.836	.73	.023	.105	.028	1080	.80	.037	.107	.047	29.2
"	"	7	.883	.74	.030	.100	.038	.817	.73	.027	.099	.035	-7.5
"	"	11	.885	.72	.031	.085	.036	.845	.73	.027	.086	.038	-4.5
"	"	16	.874	.78	.026	.101	.034	.858	.78	.029	.106	.035	-1.8
"	"	18	.893	.77	.027	.099	.032	.889	.77	.027	.111	.034	- .5
"	"	22	.891	.76	.027	.095	.033	.869	.77	.027	.089	.033	-2.5
"	"	41	.882	.77	.028	.105	.035	.875	.76	.028	.098	.035	- .8
"	"	43	.875	.77	.027	.098	.033	.873	.78	.027	.097	.033	- .2
"	"	46	.873	.76	.026	.100	.034	.887	.76	.028	.109	.036	-1.6
"	"	48	.882	.77	.029	.099	.035	.864	.76	.027	.097	.034	-2.0
"	"	53	.870	.74	.031	.090	.040	.847	.73	.029	.085	.038	-2.6
"	"	58	.873	.77	.028	.100	.034	.793	.76	.030	.097	.030	-9.2
"	"	60	.875	.76	.029	.102	.032	.873	.77	.027	.109	.034	- .2
	Average		.877	.76	.028	.099	.034	.874	.76	.028	.100	.035	-0.3
Average all D rails			.873	.76	.028	.099	.034	.881	.76	.029	.100	.036	0.9
Yes	E	56	.891	.76	.025	.090	.035	.853	.75	.024	.091	.031	-4.3
No	E	2	.891	.75	.026	.108	.035	.855	.76	.024	.089	.030	-4.0
"	"	3	.891	.76	.027	.108	.034	.846	.76	.026	.106	.033	-5.1
"	"	12	.846	.75	.023	.104	.023	.936	.77	.030	.110	.039	10.6
"	"	24	.873	.73	.031	.100	.036	.838	.73	.028	.097	.034	-4.0
"	"	25	.891	.75	.028	.098	.035	.845	.75	.026	.101	.035	-5.2
"	"	45	.887	.76	.025	.098	.034	.828	.75	.024	.098	.032	-6.7
	Average		.880	.75	.027	.103	.033	.858	.75	.026	.100	.034	-2.5
Average all E rails			.882	.75	.026	.101	.033	.857	.75	.026	.099	.035	-2.8
Yes	F	1	.873	.77	.026	.104	.032	.832	.75	.023	.117	.031	-4.7
"	"	26	.870	.75	.023	.098	.036	.836	.74	.026	.104	.034	-3.9
"	"	32	.855	.74	.029	.092	.034	.805	.74	.025	.096	.030	-5.9
"	"	38	.869	.76	.026	.117	.034	.787	.74	.023	.115	.033	-9.4
"	"	49	.844	.74	.029	.094	.037	.818	.71	.027	.094	.038	-3.1
"	"	52	.879	.75	.026	.099	.034	.800	.74	.025	.098	.032	-9.0
"	"	54	.884	.75	.026	.110	.031	.840	.74	.023	.090	.032	-5.0
"	"	55	.894	.80	.026	.101	.035	.795	.76	.025	.096	.030	11.1
"	"	59	.876	.74	.028	.111	.034	.791	.73	.026	.092	.032	-9.2
"	"	61	.876	.74	.030	.097	.035	.796	.75	.025	.087	.033	-9.1
	Average		.872	.75	.027	.102	.034	.810	.74	.025	.099	.033	-7.1
No	F	8	.908	.77	.028	.113	.036	.900	.78	.027	.117	.036	- .9
"	"	9	.891	.75	.029	.094	.034	.911	.74	.030	.103	.032	2.2
"	"	10	.887	.80	.028	.125	.034	.905	.79	.029	.139	.035	2.0
"	"	19	.889	.76	.028	.094	.035	.920	.76	.032	.103	.038	3.5
"	"	27	.891	.74	.030	.088	.036	.830	.73	.030	.098	.036	-6.9
"	"	28	.901	.75	.029	.102	.034	.882	.76	.029	.100	.033	-2.1
"	"	29	.808	.66	.024	.193	.032	.873	.66	.022	.191	.032	8.0
"	"	34	.898	.75	.027	.089	.035	.895	.75	.026	.100	.034	- .3
"	"	35	.866	.74	.028	.097	.033	.849	.75	.027	.101	.031	-2.0
"	"	36	.887	.76	.027	.113	.035	.898	.77	.027	.116	.034	1.2
"	"	51	.896	.77	.028	.098	.036	.820	.77	.025	.093	.033	-8.5
	Average		.884	.75	.028	.110	.035	.880	.75	.028	.115	.033	-0.5
Average all F rails			.878	.75	.027	.106	.034	.847	.75	.026	.107	.033	-3.5
Yes	All	20	.871	.75	.027	.102	.034	.841	.75	.026	.099	.034	-3.5
No	"	41	.878	.76	.028	.102	.034	.882	.76	.028	.104	.035	0.5
Total	"	61	.876	.75	.027	.102	.034	.868	.76	.027	.102	.035	-0.9

The average composition of the steel as poured from the ladle would be fairly well represented by the average of all the results from the O position and these are given below in comparison with the ladle analysis as taken from the inspection record.

	C	Mn	P	Si	S
Ladle analysis	.72	.74	.022	.12	.032
Rails	.876	.75	.027	.102	.034

It will be noted the results are in fair agreement except as to carbon, which was much higher in the rails than shown by the inspection record.

For convenience of comparison the average carbon results for the several groups are collected together in Table 5.

TABLE 5—AVERAGE CARBON RESULTS.

Rail Letter	Rails with Fissures				Rails without Fissures				All Rails			
	No.	Carbon O	Carbon M	% Seg.	No.	Carbon O	Carbon M	% Seg.	No.	Carbon O	Carbon M	% Seg.
B	5	.868	.871	0.3	5	.859	.923	7.4	10	.864	.897	3.8
C	3	.887	.884	—4.9	5	.882	.893	1.2	8	.884	.875	—1.0
D	1	.818	.983	20.2	14	.877	.874	—0.3	15	.873	.881	0.9
E	1	.891	.853	—4.3	6	.880	.858	—2.5	7	.882	.857	—2.8
F	10	.872	.810	—7.1	11	.884	.880	—0.5	21	.878	.847	—3.5
All	20	.871	.841	—3.5	41	.878	.882	0.5	61	.876	.868	—0.9

The rails with fissures were in a general way chemically the same as the rails without fissures, but one noticeable feature is that the carbon in the interior metal of the rails with fissures tended to run several points lower than in the interior metal of the rails without fissures, except in the case of one D rail with a fissure and it seems probable that this was really an A rail. In this rail the outer metal showed lower carbon

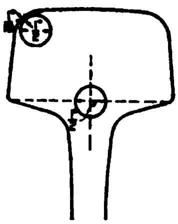


FIG. 9—LOCATIONS OF SAMPLES FOR ANALYSIS.

and the interior metal showed higher carbon than the general average, which condition indicates strongly that it was an A rail, and either was stamped with the wrong letter on the rail, or an error made in the record. As a general average the rails with fissures showed 3.5 per cent. negative segregation in the M position, while the rails without fissures showed 0.5 per cent. positive segregation. It thus appears that the trans-

TABLE 6—TENSILE TESTS.

Fissures Found	Rail Letter	Rail No.	O Position Yl.Pt.	T.S.	Elong.	Red.	M Position Yl.Pt.	T.S.	Elong.	Red.
Yes	B	13	58100	138900	11	5.3	53380	90160	2	2.2
"	"	14	57000	138800	11	13.0	57520	78660	1	1.6
"	"	31	61180	125700	4	5.7	63440	107550	2	3.7
"	"	33	60550	135150	10	14.8	61020	86260	2	1.0
"	"	39	61500	87550	9	8.0	62260	89760	2	1.3
	Average		59666	125220	9.0	9.4	59524	90476	1.8	1.9
No	B	5	57260	135950	9	13.8	60800	108250	2	4.0
"	"	15	60950	136600	10	13.5	60540	111750	2	3.0
"	"	37	56260	137250	10	10.2	55120	117400	4	5.2
"	"	44	56820	133900	9	12.6	56600	109750	3	3.4
"	"	57	59560	117100	3	3.9	59420	118750	3	3.9
	Average		58170	132160	8.2	10.8	58496	113180	2.8	3.9
Average all B rails			58918	128690	8.6	10.1	59010	101829	2.3	2.9
Yes	C	20	61220	140900	11	11.8	58200	82160	2	1.5
"	"	21	56150	120400	--	--	58160	87320	2	2.0
"	"	30	60600	142250	10	12.1	60300	95600	2	1.0
	Average		59323	134517	10.5	12.0	58887	88360	2.0	1.5
No	C	17	67100	141500	10	13.4	68780	143200	6	5.1
"	"	40	53460	136900	9	12.4	60840	141450	9	10.8
"	"	42	61240	139650	10	3.0	59860	107400	3	2.7
"	"	47	58820	139250	11	12.4	62400	97220	1	2.5
"	"	50	61840	144250	10	11.4	63260	85260	-	-
	Average		60492	140310	10.0	10.5	63028	114906	4.8	5.3
Average all C rails			60054	138125	10.1	10.9	61475	104951	3.6	3.7
Yes	D	23	61500	133500	9	12.5	59600	81150	1	1.5
No	D	4	63380	136000	11	11.9	61040	131100	6	5.7
"	"	6	60340	135100	12	14.3	61300	92940	2	2.2
"	"	7	54820	136050	11	13.4	53680	98660	3	2.5
"	"	11	55400	132100	10	13.5	54260	118700	4	5.2
"	"	16	59500	132800	8	12.7	59200	123950	-	-
"	"	18	54900	140450	10	13.0	55460	114200	3	3.8
"	"	22	58400	138150	10	11.9	58600	119350	4	3.5
"	"	41	57580	136400	10	11.1	57340	125050	5	2.8
"	"	43	54050	132900	10	11.5	54620	131400	9	9.3
"	"	46	58300	136000	9	10.9	61740	109900	3	2.2
"	"	48	55580	133400	10	12.7	57160	95480	3	2.7
"	"	53	56720	135350	10	13.9	54920	82900	2	2.2
"	"	58	56680	131350	10	14.1	54980	114700	3	4.4
"	"	60	60500	135750	11	12.6	58060	102400	3	2.0
	Average		57582	135057	10.1	12.7	57311	111481	3.8	3.7
Average all D rails			57843	134953	10.1	12.7	57464	109459	3.6	3.6
Yes	E	56	55940	135900	11	11.8	55780	69840	-	-
No	E	2	57240	132950	5	6.0	54400	97600	-	-
"	"	3	62620	137600	--	--	60850	101600	3	2.0
"	"	12	54720	130200	--	--	54280	123100	3	3.2
"	"	24	58960	134800	9	12.4	63320	116500	4	4.0
"	"	25	57750	139600	10	13.5	53340	92800	2	2.5
"	"	45	65180	140650	11	12.6	57250	92400	2	1.8
	Average		59412	135966	8.8	11.1	57240	103966	2.8	2.7
Average all E rails			58916	135957	9.2	11.3	57031	99077	2.8	2.7
Yes	F	1	56180	139150	12	15.9	53500	78250	-	-
"	"	26	59600	137000	11	13.0	57450	103800	2	3.0
"	"	32	54650	137050	11	13.5	51340	74040	2	2.5
"	"	38		Tr.Fis			52780	66140	1	2.0
"	"	49	59500	135300	10	10.6	56660	97660	2	2.0
"	"	52	56650	137950	11	14.0	56120	68280	-	-
"	"	54	57160	136600	11	13.9	54000	102700	2	3.5
"	"	55	62980	136350	9	13.9	59700	102250	3	2.2
"	"	59	56400	134500	11	14.3	54780	83040	-	-
"	"	61	55250	136400	10	13.0	55920	94000	2	3.2
	Average		57597	136700	10.7	13.6	55225	87016	2.0	2.6
No	F	8	64700	138750	9	13.5	62900	108300	-	-
"	"	9	56920	134600	5	5.6	55860	117400	-	-
"	"	10	60150	140100	10	12.5	62350	125300	-	-
"	"	19	61520	141500	11	12.7	58550	72950	1	1.0
"	"	27	60350	140050	10	13.5	59260	79100	1	4.0
"	"	28	58500	139250	10	14.5	57980	117850	4	3.5
"	"	29	58700	132800	14	19.0	57040	125200	16	18.7
"	"	34	60200	139450	--	--	57600	136800	9	11.8
"	"	35	58320	137650	10	13.9	58200	104700	-	-
"	"	36	58000	140700	10	13.6	58820	113500	3	3.4
"	"	51	56760	139900	10	12.4	55080	132100	11	12.7
	Average		59284	138614	9.9	13.1	58515	112109	6.4	7.8
Average all F rails			58525	137753	10.3	13.3	56947	100160	4.2	5.3
Yes	All	20	58532	133124	10.1	12.1	57096	86931	1.9	2.1
No	"	41	58733	136432	9.7	12.2	58465	111197	4.2	4.6
Total	"	61	58669	135384	9.8	12.1	58016	103224	3.4	3.8

verse fissure rails of this heat would have passed any chemical requirements in rail specifications, limiting the amount of allowable segregation of carbon.

Tensile Tests.

Two specimens were cut for tensile tests from near the middle of each rail, one from the O position near an upper corner of the head and one from the M position from the interior of the head near the web. The specimens were one-half inch in diameter with a gage length of two inches. The yield point was determined by means of a Berry strain gage. The results of the tests are given in Table 6, grouped by ingot positions of the rails and the presence or absence of fissures as disclosed by the drop or quick bend tests. In the table, the yield point and tensile strength are expressed in pounds per square inch, the elongation is the per cent. of stretch in two inches and the reduction of area is the per cent. reduction of the original cross-section.

A study of the results shows that in the O position or outer part of the section, the metal in most cases had about normal tensile properties for .87 per cent. carbon steel and that the rails with fissures were about the same as those in which fissures were not found. In the M position or interior of the head, however, the metal showed about the same yield point as the outer metal, but was low in ductility and tensile strength. In most cases the interior metal showed very low elongation and reduction of area, and especially so in the rails with fissures. For convenience of comparison the average elongation results are collected together in Table 7.

Table 7—Average Elongations.

Rail Letter	Rails with Fissures			Rails without Fissures			All Rails		
	No.	Per cent. Elong.		No.	Per cent. Elong.		No.	Per cent. Elong.	
		O	M		O	M		O	M
B	5	9.0	1.8	5	8.2	2.8	10	8.6	2.3
C	3	10.5	2.0	5	10.0	4.8	8	10.1	3.6
D	1	9.0	1.0	14	10.1	3.8	15	10.1	3.6
E	1	11.0	....	6	8.8	2.8	7	9.2	2.8
F	10	10.7	2.0	11	9.9	6.4	21	10.3	4.2
All	20	10.1	1.9	41	9.7	4.2	61	9.8	3.4

In this table, the notable feature is the low elongation of the metal in the interior of the head, averaging only 1.9 per cent. in the rails that disclosed fissures and 4.2 per cent. in the rails without fissures. All of the rails that disclosed fissures showed very low interior elongation, but there were a few rails in which fissures were not found, that showed good interior elongation.

The number of fissures found in a rail as related to the elongation of the metal in the interior of the head is shown in Fig. 10, in which the elongation is plotted horizontally and the number of fissures in the

TABLE 8—QUICK BEND TESTS.

Fissures Found	Rail Letter	Rail No	Elastic Limit	Breaking Load	Ultimate Deflection	Elong. percent
Head in Tension						
Yes	B	14*		trans.fis.		
"	B	33*		trans.fis.		
"	E	56	80784	104544	.21	0
"	F	26*		trans.fis.		
"	F	32	97416	140184	.30	1
"	F	49		95040	.18	0
"	F	52	95040	171072	.58	2
	Average		91080	127710	.32	0.8
No	B	15	83160	211464	1.12	4
"	B	44	99792	232848	1.13	4
"	C	17	97416	244728	1.22	5
"	C	40	111672	285120	2.11	10
"	C	42	97416	156816	.44	1
"	C	47	114048	178200	.46	2
"	C	50	92664	168696	.44	2
"	D	6	106920	185328	.59	2
"	D	11	85536	168696	.55	2
"	D	16	85536	266112	1.58	6
"	D	18	95040	273240	1.44	6
"	D	22	87912	220968	1.23	4
"	D	41	85536	220968	1.00	4
"	D	48	95040	249480	1.70	7
"	D	53	90288	218592	1.07	4
"	D	60	97416	168696	.51	2
"	E	3	106920	180576	.56	2
"	E	12	85536	206712	.94	4
"	E	25	90288	137808	.38	1
"	E	45	95040	171072	.53	2
"	F	10	95040	220968	.96	4
"	F	28	95040	121176	.26	1
"	F	35	99792	168696	.53	2
"	F	51	92664	192456	.84	3
	Average		95238	205392	.90	3.6
Av. all head in tension			94776	194295	.82	3.1
Base in Tension						
Yes	B	13	90288	318384	2.93	12
"	B	31	92664	254232	1.47	5
"	B	39	92664	168696	.52	1
"	C	20*	95040	318384	2.87	12
"	C	21*	76032	339768	3.16	13
"	C	30	83160	316008	2.35	8
"	D	23	92664	261360	1.48	4
"	F	1	97416	354024	2.71	11
"	F	38*	104544	313632	3.00	13
"	F	54	92664	308880	2.79	18
"	F	55*	92664	287496	2.90	12
"	F	59*	95040	327888	2.81	10
"	F	61	102168	299376	2.28	8
	Average		92847	297548	2.41	9.3
No	B	5	85536	275616	1.85	6
"	B	37	102168	287496	1.92	5
"	B	57	95040	282744	1.68	5
"	D	4	104544	377784	2.52	9
"	D	7	111672	268488	1.48	4
"	D	43	78408	277992	2.35	8
"	D	46	92664	220968	1.02	3
"	D	58	92664	275616	1.88	6
"	E	2	83160	280368	2.03	6
"	E	24	85536	256608	1.43	4
"	F	8	80784	332640	2.82	12
"	F	9	95040	237600	1.20	4
"	F	19	92664	332640	2.92	13
"	F	27	78408	308880	2.59	9
"	F	29	64152	270864	2.56	10
"	F	34	95040	273240	2.24	11
"	F	36	97416	304128	2.87	12
	Average		90288	286098	2.08	7.4
Av. all base in tension			91397	291060	2.22	8.3

* Transverse fissure found in quick bend test.

rail is plotted vertically. It will be noted that with one exception, the rails with fissures showed two per cent, or less, interior elongation; in other words, fissures were not found in rails that showed three per cent. or more elongation of the interior metal of the head, with the

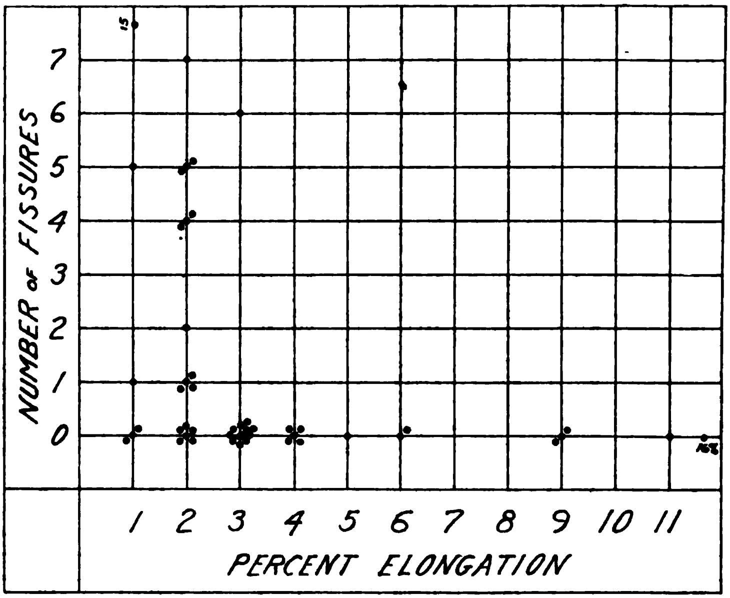


FIG. 10—NUMBER OF FISSURES FOUND IN A RAIL AS RELATED TO THE ELONGATION OF THE METAL IN THE INTERIOR OF THE HEAD.

exception of one rail with six fissures that showed three per cent. interior elongation. To what extent the difference existed in the original rails, and to what extent it may have developed in service, this investigation did not disclose.

QUICK BEND TESTS.

A quick bend test was made of a sample from the middle of each rail, in the Pennsylvania Railroad hydraulic bending machine as described in a paper presented to the American Railway Engineering Association. (See Proceedings for 1917, Vol. 18, p. 1081.) The rail was supported on supports three feet apart and pressure applied at the middle by means of a hydraulic plunger, which bent the rail till it broke. An automatic record was taken on an indicator card from which could be calculated the elastic limit, the breaking load and the deflection of the rail. The part in tension was also stamped with six one-inch spaces and their elongation measured after breaking the rail. Thirty-one of the rails were tested with the head in tension and the other thirty were tested with the base in tension. The results of the tests are given in Table 8

which gives the elastic limit in bending between three-foot supports expressed in lbs., the breaking load in lbs., the deflection at breaking in inches, and the per cent. of elongation of the inch space which stretched most, that is, the "biggest" inch. The results are divided into two groups, head in tension and base in tension, and each of these again divided into two groups, the rails in which fissures were found in the drop or quick bend tests, and those in which fissures were not found.

A study of these results proves interesting and instructive, and for convenient comparison the group averages are collected together in Table 9.

TABLE 9—AVERAGE RESULTS IN QUICK BEND TESTS.

	Head in Tension			Base in Tension		
	Rails with Fissures	Rails without Fissures	All Rails	Rails with Fissures	Rails without Fissures	All Rails
Elastic limit, lbs.....	91,080	95,238	94,776	92,847	90,288	91,397
Breaking load, lbs....	127,710	205,392	194,295	297,548	286,098	291,060
Deflection, ins........	.32	.90	.82	2.41	2.08	2.22
Elongation, per cent..	0.8	3.5	3.1	9.3	7.4	8.3

There is a considerable difference between the results with the head in tension and those with the base in tension. Most of rails when tested with the base in tension showed good strength and ductility, including the five rails which showed fissures in the head after breaking in this test with the base in tension. It is evident that the presence of fissures in the head did not affect the result with the base in tension. With the head in tension, however, the most of the rails showed a low strength and low elongation, and this is the method that should be used in order to form an idea of the qualities of the metal in the interior of the head.

OTHER TESTS.

A section from the head of each of the sixty-one rails was polished, etched with copper-potassium chloride solution, and then repolished with tripoli and examined for small cracks. No cracks were found except in those rails in which another section had shown evidence of split head.

A sulphur print was made of a cross-section from each rail. Most of them showed a uniform structure throughout the section and it is considered unnecessary to reproduce them.

A number of the rails were examined microscopically and a special examination was made along the edge of one of the transverse fissures in rail 38, to determine whether there was any noticeable variation in the structure of the steel from the center of the transverse fissure out into the normal steel surrounding. Progressive photomicrographs were taken at 100 magnifications along the edge of the fissure and the panoramic view of this is shown in Fig. 11, full size. This shows a uniform entectoid structure throughout and does not indicate any variation in

structure at any point along the transverse fissure from that found along the edge of the break produced in the drop test.

SUMMARY.

1. Tests were made of a heat of 100-lb. rails in which five rails had failed in track showing transverse fissures. Sixty-one rails were gathered in, sent to the Altoona Laboratory of the Pennsylvania Railroad and subjected to drop, chemical, tensile, quick bend, etching and microscopic tests.

2. A section six ft. long was cut from the middle of each rail by means of an oxygen-acetylene torch and used for the several tests. The remaining two long pieces were subjected to drop tests to disclose any fissures in them.

3. The rails were dropped on every 18 inches throughout their length on supports 36 inches apart, head down, using a tup of 1640 lbs. from a height of six ft. In this test, 69 fissures were found distributed among 20 rails, mostly B, C and F rails, with only a few fissures in the D and E rails. There were no A rails, as they had been rejected in the original inspection.

4. In addition to the breaks showing fissures, there were 333 breaks without fissures. In most of these plain breaks, the fracture lines radiated from a point in the interior of the head, showing the break to have started at the inside, averaging about 7/8 inch from the top of the head and about 1/8 inch from the center line toward the gage side. The centers of the nuclei of the fissures averaged 5/8 inch from the top of the head and about 9/32 inch from the center line toward the gage side.

5. Two samples were taken for analysis from near the middle of each rail, one from the O position near an upper corner of the head, and the other from the M position in the interior of the head near the web. The average composition of the steel in the rails was as follows: carbon, .876 per cent.; manganese, .75 per cent.; phosphorus, .027 per cent.; silicon, .102 per cent; sulphur, .034 per cent.

6. The rails with fissures were in a general way chemically the same as those without fissures, but showed a tendency to be a little lower in carbon in the interior of the head. The rails with fissures as a general average, showed 3.5 per cent. negative segregation of carbon in the M position and the rails without fissures showed 0.5 per cent. positive segregation, as compared with the O position.

7. Two specimens were cut for tensile tests from near the middle of each rail, one from the O position and the other from the M position. The metal in the O position or outer part of the section had about normal tensile properties for .87 per cent. carbon steel and the rails in which fissures were found were about the same as those in which fissures were not found. The metal from the interior of the head was low in ductility and particularly so in the rails in which fissures had been found.

8. The interior metal of the head in rails that showed fissures displayed two per cent. or less elongation, except in one case where the elongation was three per cent.

9. A quick bend test was made of a sample from the middle of each rail, in the Pennsylvania Railroad hydraulic bending machine, part of the rails with the head in tension and part with the base in tension. When tested with the base in tension, most of the rails showed good strength and ductility, including some that showed fissures in the head after breaking, which indicates that the testing of a rail with the base in tension does not disclose a flaw or defective condition in the interior of the head. With the head in tension, however, the most of the rails showed low strength and low elongation, which indicates that a rail should be tested in this manner.

10. Microscopic examination indicated that the core of a fissure was structurally about the same as the surrounding metal.

11. In conclusion, the results of this investigation may be summarized as follows: The carbon in the rails averaged .87 per cent., which is higher than usual for 100-lb. rails, but the elements were fairly evenly distributed throughout the section and there was, in general, freedom from "segregation." The several mechanical tests showed about normal physical properties in the rail metal, except in the interior of the head where the metal was very low in ductility. The tests also showed that to detect this condition, the rails should be tested with the head in tension; that is, the rails should be bent with the head resting on the supports.

Appendix D.

INTERIOR FISSURE RAILS ON THE BALTIMORE & OHIO RAILROAD—HEAT 5X157.

By M. H. Wickhorst, Engineer of Tests, Rail Committee.

This report gives the results of an examination of a heat of rails on the Baltimore & Ohio Railroad, which was removed from service on account of four rails breaking and showing interior fissures. Through the kindness of the officials of the Railroad, the rails of this heat were rounded up as far as possible and an investigation made of them by the Test Department at Baltimore. The rails had been laid at several locations, as shown in Table 1.

Table 1—Locations of Rails

Location.	*East or West Bound.*	*Million Tons Over Rail.*	*Grade.*	*Nature of Traffic.*
Catoctin	E. B.	16.0	—0.28%	Heavy freight predominates.
Section 34 Metropolitan Branch	E. B.	3.25	—1.1%	Passenger predominates
Section 37 Metropolitan Branch	E. B.	3.25	—1.07%	do
Section 39 Metropolitan Branch	E. B.	3.3	+1.1%	do
Section 39 Metropolitan Branch	W. B.	3.3	—1.1%	do
Mt. Winans	E. B.	7.0	—0.794%	Mixed pass. and freight
Gay Street	E. B.	8.8	—0.633%	do
Gay Street	W. B.	6.8	+0.633%	do

The rails were of the 100-lb. A. R. A. type B section, made in September, 1916, at the Sparrows Point Works of the Bethlehem Steel Company. The heat number was 5X157, made by the duplex process, and consisted of 21 ingots, 21x23 inches at the bottom end, five rails per ingot, thus making 105 rails. In the inspection of the rails, they were subjected to a drop test from a height of 18 ft. with a tup weighing 2,000 lbs., with the results shown in table 2.

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TABLE 2—ORIGINAL DROP TESTS.

	Ingot Number 2	11	22
First Test—A Rails.			
Part in tension	Base	Head	Base
Number of blows	1	1	1
Effect	Broken	Broken	Broken
Retest—B Rails.			
Part in tension	Head	Base	Head
Number of blows	2	2	2
Effect	O. K.	O. K.	O. K.
Nicked and broken	O. K.	Piped	O. K.
Set first blow	1.0 in.	1.0 in.	1.0 in.
Retest—C Rails.			
Part in tension	Base	Head	Base
Number of blows	2	2	2
Effect	O. K.	O. K.	O. K.
Nicked and broken	O. K.	O. K.	O. K.
Set first blow	1.0 in.	1.1 in.	1.1 in.

It will be noted that the three pieces first tested broke on the first blow, and the 21 A rails were therefore rejected. When the B rails were retested, they stood the drop test, but one of the test pieces, when nicked and broken, showed a "pipe" and the 21 B rails were accepted as "specials." The retest of the C rails stood all tests and the other 63 rails of the heat, consisting of C, D and E rails, were accepted as first class rails. Of the 63 rails, 50 were rounded up and delivered to the Test Department at Baltimore, where an investigation was made consisting of examinations for fissures, chemical analyses, tensile tests, polishing of sections, sulphur prints and microscopic examinations. A piece fifteen inches long was cut from the middle of each rail with an oxygen-acetylene torch, for the several laboratory tests, and the two long pieces were then examined for the presence of fissures by bending at short intervals along their length in the drop machine.

DROP TESTS.

Each half of the rail was given 10 blows of a 2,000-lb. tup from a height of 8 feet, the rail being placed on supports three feet apart and being passed along after each blow. The first blow was struck about 22 inches from the end and each succeeding blow about 16 inches from the other, in all cases the head being down so as to put this part in tension and show up any fissures that might be in the head of the rail. The results of these tests are given in table 3, which shows the rails that broke under the drop, the number of breaks that disclosed fissures and the number that did not disclose fissures, grouped by location of the rails in track and sub-grouped by ingot position of the rail. The breaks without fissures were largely ones which the fracture lines showed to have

TABLE 3—RESULTS OF DROP TESTS.

Location	Curve	Rail Letter	Rail Number	Number of Breaks: With Fissures	Number of Breaks: Other Breaks	Number of Breaks: Total Breaks
Catoctin	3°30'L	B	39	....	....	....
"	"	"	43	....	....	....
"	"	C	41	....	....	....
"	"	"	42	4	....	4
"	"	"	45	3	....	3
"	"	"	49	2	1	3
"	"	D	2	10	....	10
"	"	"	38	5	....	5
"	"	"	40	1	....	1
"	"	"	47	....	....	....
"	"	"	48	....	....	....
"	"	E	44	....	....	....
"	"	"	46	....	....	....
"	"	"	50	4	....	4
Gay St.	6°24'H	B	10	....	....	....
"	6°24'L	C	6	....	....	....
"	"	"	9	....	1	1
"	"	"	13	....	9	9
"	6°24'H	"	14	....	4	4
"	"	"	17	1	....	1
"	6°24'L	"	24	1	....	1
"	"	"	25	13	1	14
"	"	"	26	2	....	2
"	6°24'H	D	1	....	1	1
"	6°24'L	"	3	2	3	5
"	"	"	4	1	2	3
"	6°24'H	"	15	1	....	1
"	"	"	19	1	....	....
"	6°24'L	"	22	....	....	....
"	6°24'H	E	5	....	....	....
"	6°24'L	"	7	9	....	9
"	"	"	8	....	1	1
"	6°24'H	"	11	....	....	....
"	"	"	12	....	....	....
"	"	"	21	....	....	....
"	"	"	23	....	....	....
Mt. Winans	T	C	16	....	....	....
"	"	E	18	....	....	....
"	"	"	20	....	....	....
Metro. Br.	3°H	C	28	....	....	....
"	1°10'L	"	30	....	....	....
"	3°H	"	33	....	....	....
"	T	"	36	....	2	2
"	1°10'L	D	29	....	....	....
"	Spiral H	"	34	....	7	7
"	T	"	37	....	....	....
"	3°H	E	27	....	....	....
"	T	"	31	....	....	....
"	1°10'L	"	32	....	5	5
"	45'L	"	35	....	8	8

started at the top surface of the head. These also showed hardened metal at the surface, due evidently to driver slippage. A few other breaks showed seams in the base where struck by the tup and a few showed splits or "pipes" in the head, but for the purposes of this investigation it will be necessary to consider only the breaks that showed fissures.

TABLE 4—SUMMARY OF DROP TESTS.

Rail Letter	Number of Rails	LOCATION			
		Catoctin	Gay St	Mt. Winans	Metro Br.
C	Total No. with fis. % with fis.	4 3 75%	8 4 50%	1 0 0%	4 0 0%
D	Total No. with fis. % with fis.	5 3 60%	6 4 67%	0 0 0%	3 0 0%
E	Total No. with fis. % with fis.	3 1 33%	7 1 14%	2 0 0%	4 0 0%
All	Total No. with fis. % with fis.	12 7 58%	21 9 43%	3 0 0%	11 0 0%

Table 4 gives a summary of the results showing the rails classified by ingot position of the rail and the location in track. It will be noted that the 16 rails that showed fissures had been located at Catoctin with about 16 million tons of mostly heavy freight traffic and at Gay Street with about half the tonnage, also largely heavy freight. In the rails located at Mt. Winans with about 7 million tons of mixed passenger and freight traffic and on the Metropolitan Branch with about 3¼ million tons of mostly passenger traffic, no fissures were found in 14 rails.

It will also be noted that the percentage of E rails with fissures was much less than of the C and D rails. The A rails of the heat had been rejected in the drop test and the B rails had been accepted as "specials," intended for minor service, although three of them were gathered in the round-up.

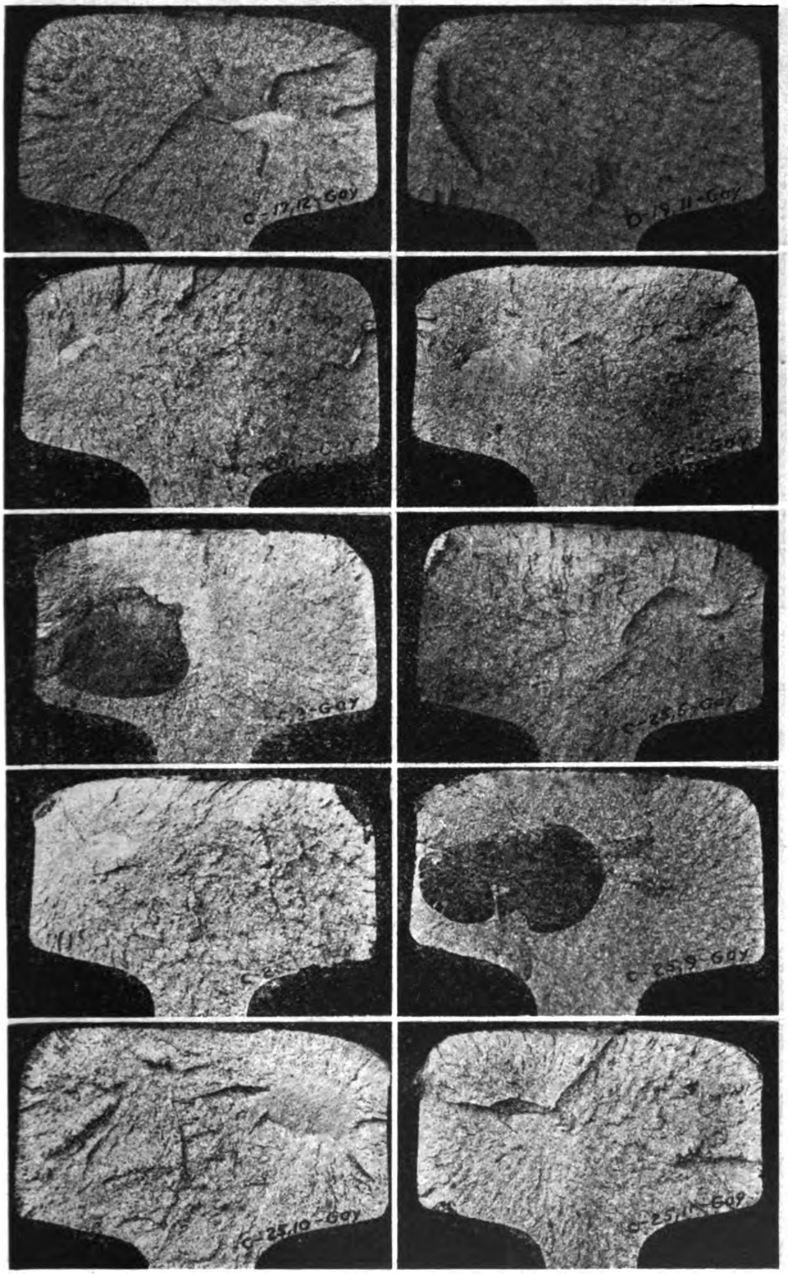

FIG. 1—FRACTURES SHOWING FISSURES IN C RAILS.

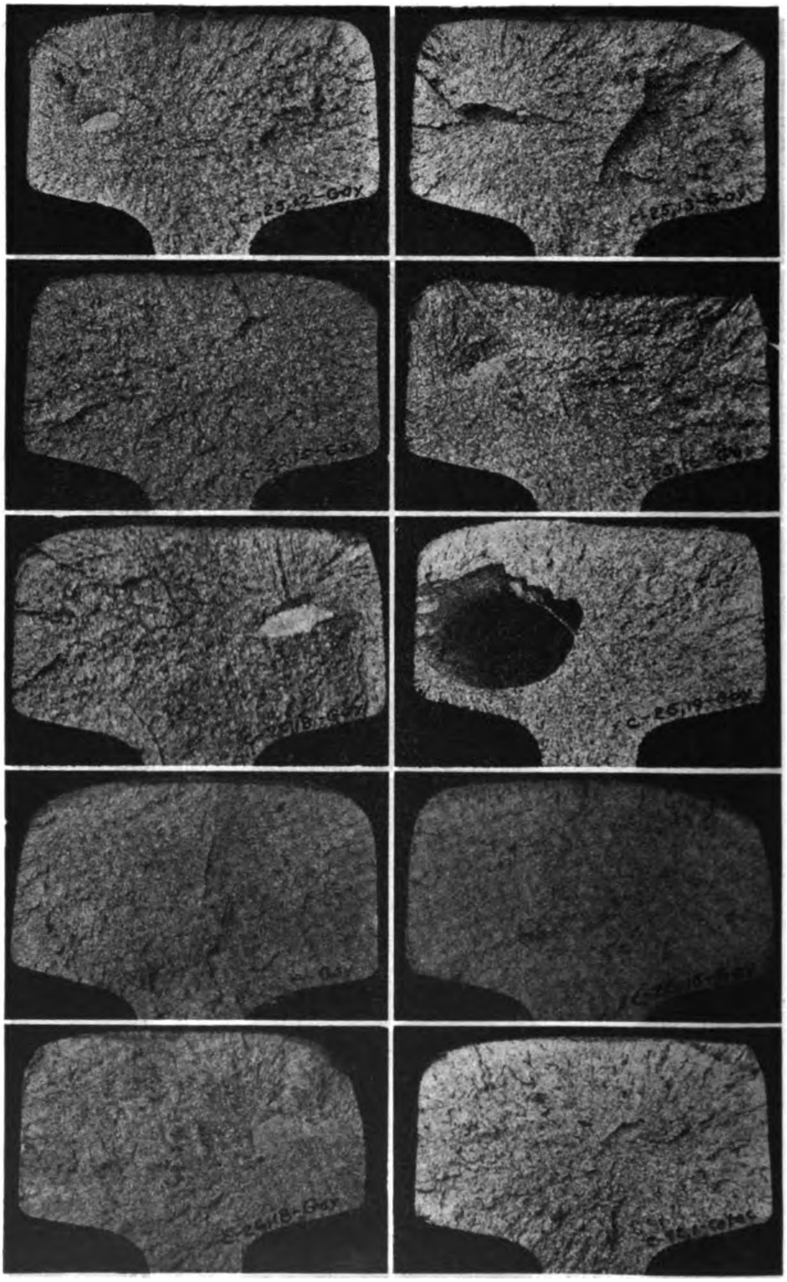

FIG. 2—FRACTURES SHOWING FISSURES IN C RAILS.

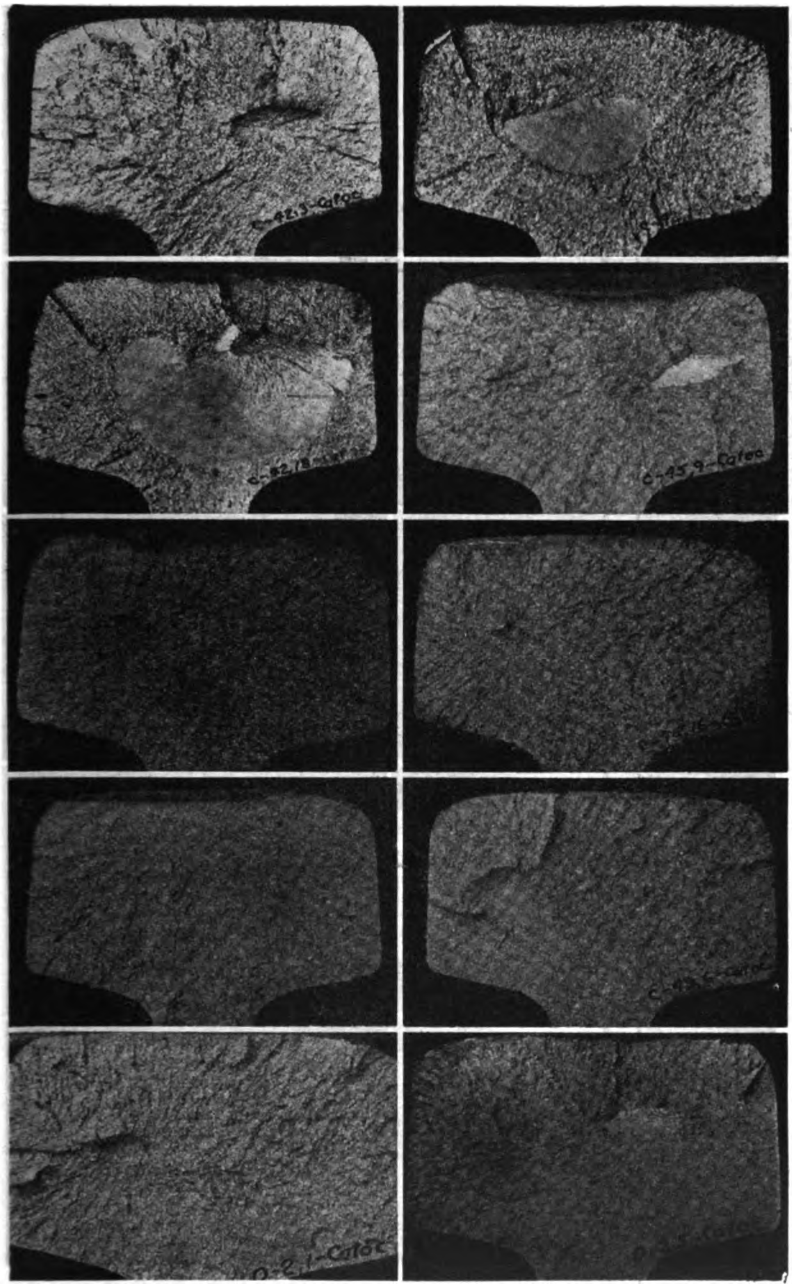

Fig. 3—Fractures Showing Fissures in C anp D Rails.

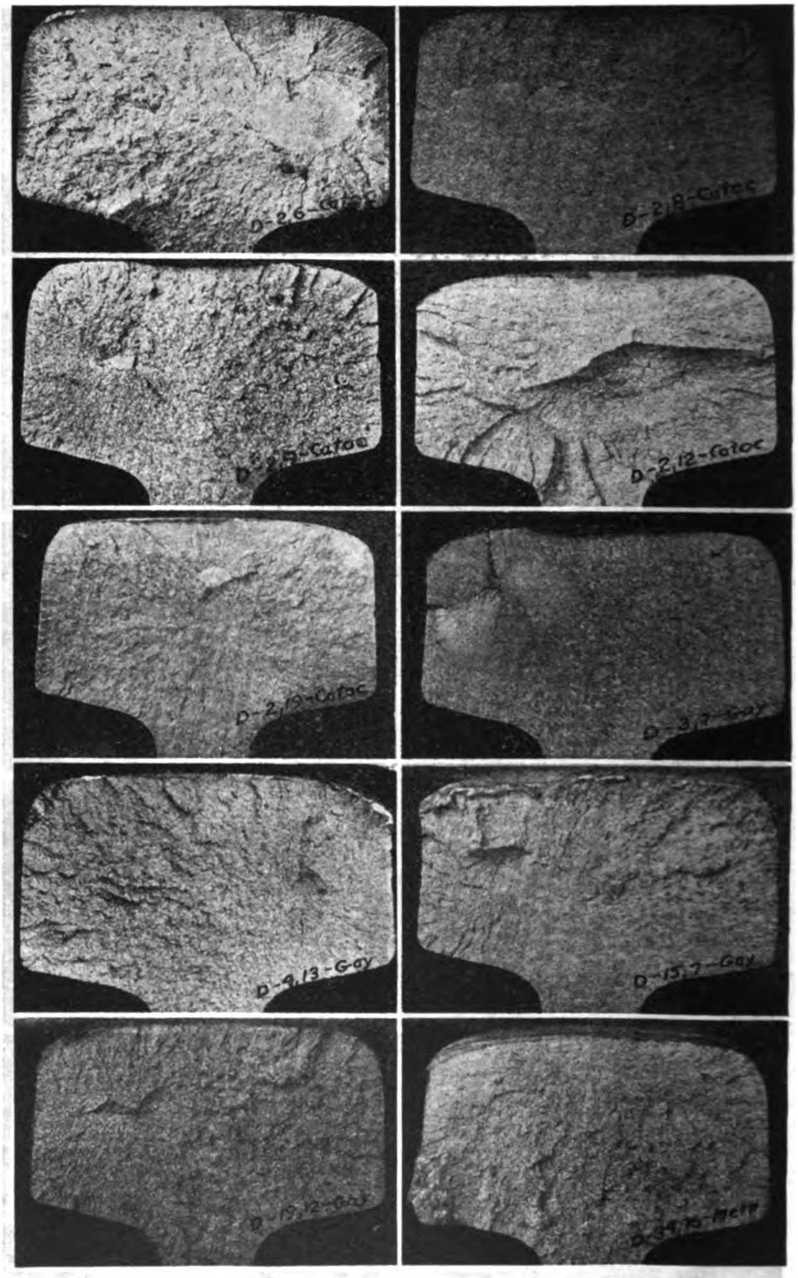

FIG. 4—FRACTURES SHOWING FISSURES IN D RAILS.

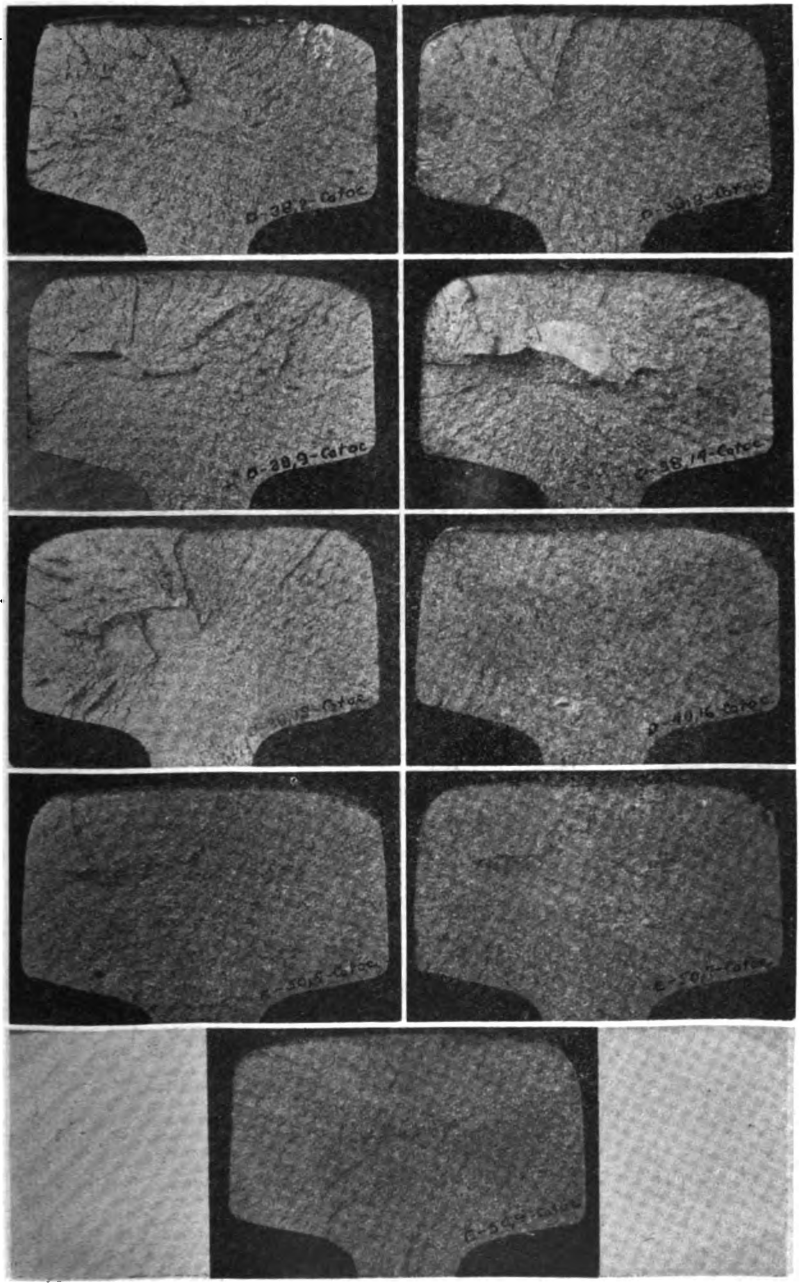

FIG. 5—FRACTURES SHOWING FISSURES IN D AND E RAILS.

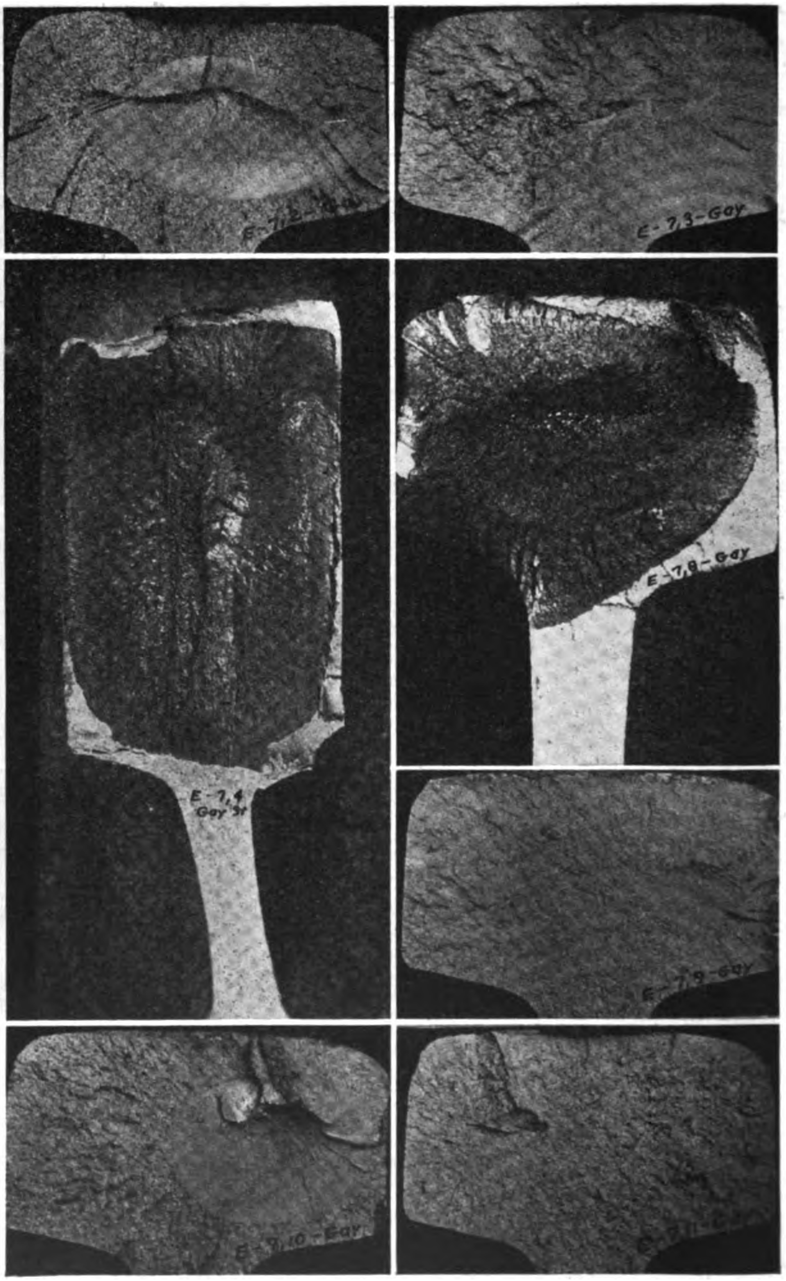

FIG. 6—FRACTURES SHOWING FISSURES IN E RAILS.

FRACTURES.

A photograph was made of each of the fractures that showed a fissure and these are reproduced in figs. 1 to 6, inclusive. Fifty-six such fractures are shown distributed among sixteen rails arranged according to ingot position of the rail and by rail number. On each illustration of a fracture is shown the rail letter, the location of the rail in the track and a number, the first part of which is the rail number and the second part of which is the number of the blow from the end of the rail, on which the fracture occurred.

An examination of the illustrations shows that the fissures were mostly of the compound type; that is, they consisted of longitudinal horizontal fissures with transverse branches issuing from them. There were also some "split heads;" that is, longitudinal fissures or splits in the interior of the head, vertical or obliquely vertical. There were very few, if any, simple transverse fissures, consisting of a core or nucleus with the fissure issuing transversely from it. A good illustration of the type of break represented in this lot is shown in Fig. 6, E rail number 7, break 4, which gives a top view of the fracture, disclosing the horizontal break

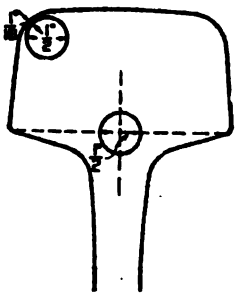

FIG. 7—POSITIONS OF SAMPLES FOR ANALYSIS. CORNER IS O POSITION AND INTERIOR IS M POSITION.

in the interior of the head. It will be noted the break issued from an interior longitudinal streak or series of streaks. The microscopic examination shed considerable light on the nature of these streaks and will be discussed later in this report.

CHEMICAL ANALYSES.

From near the middle of each rail two samples were taken for analysis, one from an upper corner of the head called the O position (outside), and the other from the interior of the head near the web, called the M position (middle), as shown in Fig. 7. Determinations were made of carbon, sulphur, phosphorus and manganese on all the samples, and in addition determinations were also made of chromium, nickel and silicon on the ten samples from rails 1 to 5, inclusive. The average composition of the steel in the rails as disclosed by these analyses is shown

below in comparison with the results of the original heat analysis as taken from the inspection report and it will be noted that the two sets of results are in close agreement as to most of the elements.

	Rail Analyses	Heat Analysis
Carbon	.65	.655
Sulphur	.053	.052
Phosphorus	.023	.027
Manganese	.78	.78
Chromium	.35	.31
Nickel	.42	.49
Silicon	.15	.146

The results of the analyses of the rails in which fissures were found are given in Table 5 and the results on the rails in which fissures were not found are given in Table 6. The average results in the two tables are collected together in Table 7 for convenience of comparison. The results on chromium, nickel and silicon are given in Table 8. A study of the results shows that the rails with fissures were chemically about the same as those without fissures and that there was a fairly uniform distribution of the elements in most of the rails. Although rail specifications do not contain a limit on sulphur, the sulphur in these rails was a little above the amount usual in rail steel.

TABLE 5—ANALYSES OF RAILS WITH FISSURES.

Rail Letter	Rail No.	O Position				M Position				% Seg Carbon
		C	S	P	Mn	C	S	P	Mn	
C	17	.70	.057	.026	.77	.67	.056	.023	.76	-4.3
"	24	.66	.054	.022	.75	.66	.054	.020	.76	0.0
"	25	.64	.057	.021	.77	.64	.057	.019	.76	0 0
"	26	.61	.054	.021	.80	.62	.053	.021	.79	1 6
"	42	.61	.060	.025	.80	.63	.059	.024	.78	3 3
"	45	.67	.052	.024	.80	.66	.051	.024	.81	-1.5
"	49	.70	.055	.025	.80	.70	.058	.023	.80	0.0
	Average	.66	.056	.023	.78	.65	.055	.022	.78	-1.5
D	2	.69	.045	.021	.77	.68	.044	.020	.77	-1.5
"	3	.72	.051	.021	.79	.67	.053	.020	.79	-7.0
"	4	.66	.056	.020	.80	.65	.057	.019	.79	-1.5
"	15	.65	.0.8	.023	.77	.64	.046	.020	.77	-1.5
"	19	.56	.0'6	.021	.76	.60	.048	.020	.77	6 7
"	38	.69	.056	.024	.80	.68	.053	.022	.80	-1.5
"	40	.73	.056	.024	.79	.73	.053	.023	.78	0.0
	Average	.67	051	.022	.78	.66	.051	.021	.78	-1.5
E	7	.60	.044	.020	.78	.59	.044	.019	.78	-1.7
"	50	.65	052	.023	.80	.64	.051	.022	.80	-1.5
	Average	.63	.048	.022	.79	.62	.048	.021	.79	-1.6
Gen. Average		.66	.053	.023	.78	.65	.052	.021	.78	-1.5

TABLE 6—ANALYSES OF RAILS WITHOUT FISSURES.

Rail Letter	Rail No.	O Position				M Position				% Seg Carbon
		C	S	P	Mn	C	S	P	Mn	
B	10	.69	.051	.024	.77	.67	.053	.024	.78	-2.9
"	39	.71	.055	.026	.79	.71	.058	.027	.80	0.0
"	43	.61	.060	.024	.80	.60	.060	.023	.80	-1.6
	Average	.67	.055	.025	.79	.66	.057	.025	.79	-1.5
C	6	.65	.054	.020	.77	.67	.054	.020	.78	3.1
"	9	.68	.055	.022	.77	.60	.052	.021	.78	-11.8
"	13	.69	.053	.028	.78	.67	.054	.022	.78	-2.9
"	14	.69	.048	.026	.79	.70	.051	.024	.78	1.5
"	16	.68	.051	.023	.79	.68	.050	.021	.79	0.0
"	28	.66	.057	.022	.78	.66	.057	.021	.79	0.0
"	30	.67	.057	.021	.78	.66	.056	.022	.77	-1.5
"	33	.73	.055	.020	.78	.72	.051	.022	.79	-1.4
"	36	.68	.057	.026	.80	.67	.057	.026	.79	-1.5
"	41	.62	.057	.026	.79	.63	.057	.026	.79	1.6
	Average	.68	.054	.023	.78	.67	.054	.023	.78	-1.5
D	1	.71	.054	.020	.77	.69	.055	.021	.76	-2.8
"	22	.66	.052	.022	.77	.65	.051	.023	.75	-1.5
"	29	.60	.057	.024	.77	.60	.057	.022	.77	0.0
"	34	.63	.052	.022	.79	.65	.052	.022	.79	3.2
"	37	.66	.056	.024	.81	.66	.054	.023	.80	0.0
"	47	.69	.054	.022	.80	.70	.056	.024	.80	1.5
"	48	.63	.050	.025	.78	.64	.050	.026	.77	1.6
	Average	.65	.054	.023	.78	.66	.054	.023	.78	1.5
E	5	.62	.048	.020	.77	.58	.047	.019	.77	-6.5
"	8	.57	.049	.017	.78	.63	.047	.015	.77	10.5
"	11	.58	.053	.023	.75	.58	.052	.021	.77	0.0
"	12	.66	.053	.022	.77	.63	.052	.017	.77	-4.6
"	18	.58	.052	.020	.75	.57	.050	.020	.77	-1.7
"	20	.60	.050	.021	.77	.60	.045	.019	.76	0.0
"	21	.64	.051	.020	.74	.64	.049	.018	.75	0.0
"	23	.64	.047	.021	.77	.63	.048	.021	.76	-1.6
"	27	.60	.050	.022	.80	.60	.052	.020	.78	0.0
"	31	.60	.054	.021	.78	.55	.048	.020	.80	-8.3
"	32	.65	.055	.022	.79	.58	.050	.021	.77	-10.8
"	35	.70	.055	.023	.80	.66	.050	.021	.79	-5.7
"	44	.59	.045	.025	.79	.58	.043	.022	.80	-1.7
"	46	.62	.052	.021	.80	.62	.050	.024	.78	0.0
	Average	.62	.051	.021	.78	.60	.049	.020	.77	-3.2
Gen. Average		.65	.053	.023	.78	.64	.052	.022	.78	-1.5

TABLE 7—AVERAGE RESULTS OF ANALYSES.

Rail Letter	O Position				M Position				% Seg. Carbon
	C	S	P	Mn	C	S	P	Mn	
	Rails with Fissures								
C	.66	.056	.023	.78	.65	.055	.022	.78	-1.5
D	.67	.051	.022	.78	.66	.051	.021	.78	-1.5
E	.63	.048	.022	.79	.62	.048	.021	.79	-1.6
Average	.66	.053	.023	.78	.65	.052	.021	.78	-1.5
	Rails without Fissures								
B	.67	.055	.025	.79	.66	.057	.025	.79	-1.5
C	.68	.054	.023	.78	.67	.054	.023	.78	-1.5
D	.65	.054	.023	.78	.66	.054	.023	.78	-1.5
E	.62	.051	.021	.78	.60	.049	.020	.77	-3.2
Average	.65	.053	.023	.78	.64	.052	.022	.78	-1.5
Gen. Ave.	.65	.053	.023	.78	.64	.052	.022	.78	-1.5

TABLE 8—CHROMIUM, NICKEL AND SILICON.

Rail No.	Rail Letter	O Position			M Position		
		Cr	Ni	Si	Cr	Ni	Si
1	D	.34	.43	.15	.33	.42	.16
2 Fis.	D	.33	.41	.15	.35	.43	.15
3 Fis.	D	.34	.41	.16	.30	.41	.15
4 Fis.	D	.37	.39	.15	.35	.39	.15
5	E	.37	.44	.15	.36	.44	.16
Average		.35	.42	.15	.34	.42	.15

TENSILE TESTS.

From near the middle of each rail two specimens were cut out for tensile tests, one from an upper corner of the head, or O position, and the other from the interior of the head near the web, or M position. The specimens were one-half inch in diameter for a gage length of two inches. The results of the tests of the rails with fissures are given in

TABLE 9—TENSILE TESTS OF RAILS WITH FISSURES.

Rail Letter	Rail No.	O Position				M Position			
		Yl. Pt.	Tens. Str.	Elong.	Red.	Yl. Pt.	Tens. Str.	Elong.	Red.
C	17	56000	143500	10.0	15.8	60200	136100	12.0	18.7
"	24	60900	143500	13.5	14.9	59800	138300	9.0	17.4
"	25	57900	141300	7.5	7.6	63600	138900	9.0	11.5
"	26	63100	142200	14.0	25.6	62300	139900	11.0	7.5
"	42	59600	142800	10.5	16.3	61900	136800	10.5	17.0
"	45	62700	143900	11.0	18.0	57700	137200	12.5	17.7
"	49	56500	146400	10.0	16.9	66500	139500	11.0	15.7
	Average.	59529	143371	10.9	16.4	61714	138100	10.7	15.1
D	2	60900	137400	7.5	9.3	62400	129800	13.0	13.0
"	3	64700	140500	12.0	17.1	63900	132000	10.0	14.4
"	4	69800	135900	11.5	18.3	59000	129900	14.0	22.7
"	15	64700	137700	12.5	18.9	66400	128800	13.5	20.3
"	19	65700	140300	13.0	18.4	62600	129900	15.0	24.1
"	38	56400	139400	12.0	18.2	62700	131200	14.0	20.1
"	40	64900	140500	11.0	16.8	55400	131400	12.5	20.9
	Average.	63871	138814	11.4	16.7	61771	130429	13.3	19.4
E	7	65500	131000	10.0	11.7	56300	120000	15.0	25.4
"	50	64600	136100	11.0	19.7	60900	129700	11.5	21.1
	Average.	65050	133550	10.5	15.7	58600	124850	13.3	23.3
Gen. Average.		62119	140150	11.1	16.5	61350	133088	12.1	18.0

Table 9 and the results on the rails in which fissures were not found are given in Table 10, grouped by ingot position or rail letter. The yield point and tensile strength are shown in pounds per square inch, the elongation is shown as the per cent. of stretch in two inches, and the reduction is shown as per cent. of the original cross-section. For more convenient comparison the average results in the two tables are collected together in Table 11. These results show in general good tensile strength and ductility in both the outer and interior parts of the head. The rails with fissures also showed about the same tensile properties as those in which fissures were not found, although the ductility was a little greater in the rails without fissures. It is interesting to note the difference in the tensile properties of the rails from the different parts of the ingot. In the outer part of the section there was some decrease in tensile strength down-

TABLE 10—TENSILE TESTS OF RAILS WITHOUT FISSURES.

Rail Letter	Rail No.	O Position				M Position			
		Yl. Pt.	Tens. Str.	Elong.	Red.	Yl. Pt.	Tens. Str.	Elong.	Red.
B									
"	10	69700	141400	13.0	21.0	69900	138800	12.5	17.4
"	39	60900	143400	10.5	17.8	61400	145100	10.5	15.7
	43	61100	146300	10.0	19.1	75300	148600	9.0	17.2
	Average.	63900	143700	11.2	19.3	68867	144167	10.7	16.8
C	6	69800	141000	10.0	18.6	68300	140800	10.0	16.9
"	9	71400	143900	13.0	24.0	68900	133100	10.0	19.4
"	13	70700	143500	12.5	20.3	71900	139300	12.0	19.5
"	14	71000	141400	13.5	20.0	67700	138400	11.0	17.0
"	16	62900	139800	12.5	20.2	63600	143200	10.5	11.1
"	28	65200	142900	13.0	18.9	61900	139300	13.0	15.1
"	30	61400	137100	....	....	59500	142200	12.5	18.5
"	33	65100	142300	13.0	18.9	63100	135800	9.0	17.0
"	36	59200	135100	11.0	14.0	67700	142000	12.0	18.6
"	41	63400	145300	11.0	17.2	56100	143500	10.5	13.8
	Average.	66010	141230	12.2	19.1	64370	139760	11.1	16.7
D	1	69200	137400	14.0	22.1	62410	129800	13.0	16.6
"	22	57400	140300	11.0	19.5	64200	132000	14.0	22.7
"	29	61700	140700	13.0	20.3	53600	132800	12.5	18.1
"	34	60100	138500	13.5	18.6	58000	128200	14.0	20.0
"	37	61400	132600	13.0	18.3	56600	139800	12.0	19.2
"	47	71300	143000	10.5	18.5	65900	133300	11.5	18.1
"	48	63400	139000	12.0	19.7	66900	135300	12.0	18.5
	Average.	63500	138786	12.4	19.6	61086	133029	12.7	19.0
E	5	61600	129800	15.0	29.5	61100	120300	18.0	28.0
"	8	71300	131400	12.5	21.9	59000	121200	15.5	25.5
"	11	72400	131400	14.0	24.1	59900	123300	15.5	25.8
"	12	69600	132800	13.0	22.7	62400	119800	15.5	26.5
"	18	66800	135100	14.0	24.3	62400	123700	16.0	24.5
"	20	57200	133100	17.0	26.9	60500	121000	17.0	27.8
"	21	56200	138600	16.0	24.0	56500	120700	17.0	27.7
"	23	55400	134100	13.0	18.8	53100	128900	12.0	19.9
"	27	59400	135800	13.5	20.2	58000	120200	17.0	27.1
"	31	58000	126300	14.0	21.6	57500	135500	14.0	23.7
"	32	55300	136600	14.0	24.6	61200	125800	15.0	23.0
"	35	56300	136600	15.0	24.6	56100	137700	15.0	15.1
"	44	61700	135300	12.5	23.5	61400	125800	13.5	23.8
"	46	62900	135200	12.5	21.2	59200	125300	14.5	22.9
	Average	61721	133721	14.0	23.4	59164	124943	15.4	24.4
Gen. Average.		63541	137853	12.9	21.1	61947	132662	13.1	20.3

ward of the ingot. In the interior of the head there was considerable decrease in strength and increase of ductility downward of the ingot. In other words, the interior metal of the ingot becomes softer as we proceed down the ingot.

TRANSVERSE TESTS OF HEAD.

Transverse tensile tests were made of the heads of the sections used in making the sulphur prints and which remained after making the microscopic tests. The test speciments were one-half inch diameter with a gage length of one inch, prepared as shown in Fig. 8. The results of the tests of the rails that showed fissures are given in Table 12 and of

TABLE 11—AVERAGE RESULTS OF TENSILE TESTS.

Rail Letter	O Position				M Position			
	Yl. Pt.	Tens. Str.	Elong.	Red.	Yl. Pt.	Tens. Str.	Elong.	Red.
Rails with Fissures								
C	59529	143371	10.9	16.4	61714	138100	10.7	15.1
D	63871	138814	11.4	16.7	61771	130429	13.3	19.4
E	65050	133550	10.5	15.7	58600	124850	13.3	23.3
Average	62119	140150	11.1	16.5	61350	133088	12.1	18.0
Rails without Fissures								
B	63900	143700	11.2	19.3	68867	144167	10.7	16.8
C	66010	141230	12.2	19.1	64370	139760	11.1	16.7
D	63500	138786	12.4	19.6	61086	133029	12.7	19.0
E	61721	133721	14.0	23.4	59164	124943	15.4	24.4
Average	63541	137853	12.9	21.1	61947	132662	13.1	20.3
Gen. Average	63086	138588	12.3	19.6	61756	132798	12.8	19.6

the rails that did not show fissures are given in Table 13, which give the tensile strength in pounds per square inch, the per cent. of elongation in one inch and the reduction of area in per cent. of the original cross-section. The average results are collected together in Table 14 for convenience of comparison.

It will be noted that most of the rails showed but little cross stretch before breaking. Most of the fractures showed streaks or the appearance of "grain" across the fracture. Some of these streaks are illustrated in Fig. 9, which shows the fractured ends of four transverse test speci-

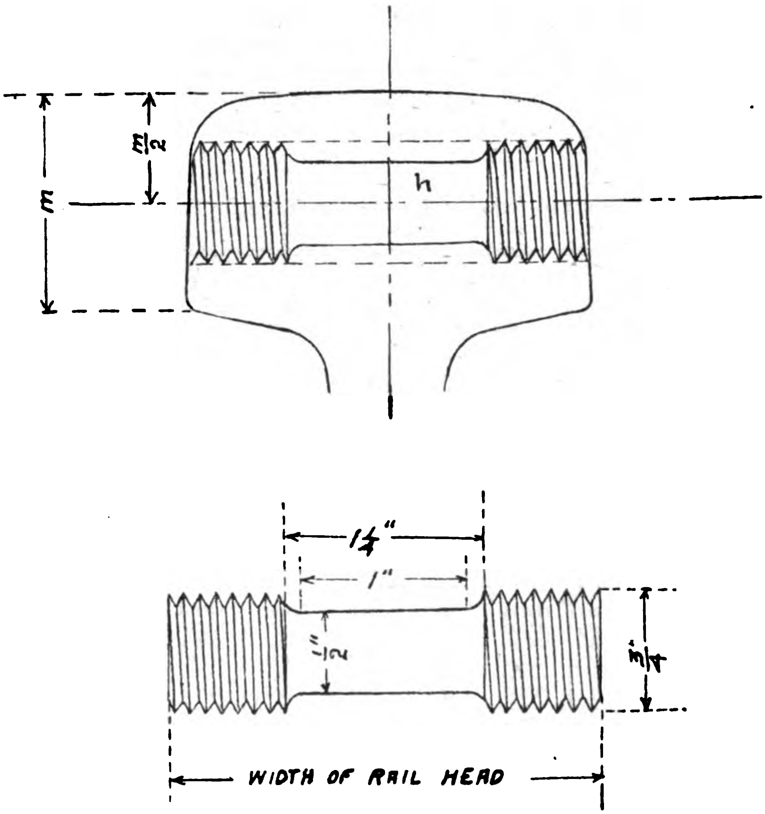

FIG. 8—SPECIMEN FOR TRANSVERSE TENSILE TEST OF HEAD.

mens. The streaks here seen were streaks in the interior of the head running lengthwise of the rail.

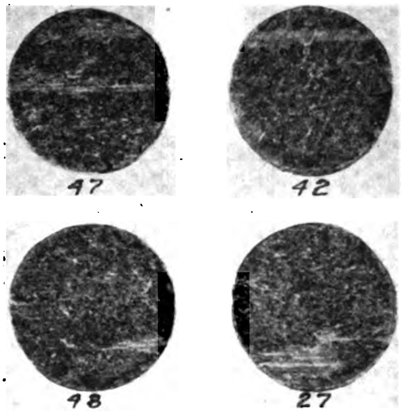

FIG. 9—FRACTURES OF TRANSVERSE TENSILE TEST SPECIMENS. ENLARGED TWO DIAMETERS. NOTE STREAKS, WHICH WERE LONGITUDINAL OF RAIL IN THE INTERIOR OF THE HEAD.

TABLE 12—TRANSVERSE TESTS OF HEAD OF RAILS WITH FISSURES.

Rail Letter	Rail No.	Tens. Str. lbs. sq. in.	Elongation Per cent.	Red. Area Per cent.
C	24	126800	4	3.1
"	25	flaw	....	......
"	26	flaw	....	.....
"	42	123550	3	3.6
"	45	134000	2	4.4
"	49	131800	4	4.3
	Average.........	129038	3.3	3.9
D	2	flaw	....	....
"	3	122800	1.5	3.2
"	15	flaw	....	....
"	19	flaw	....	....
"	38	131000	3	2.0
"	40	117000	1	0.7
	Average..........	123600	1.8	2.0
E	7	flaw	....	....
"	50	broke outside marks	....	....
Average of all.....	....	126707	2.6	3.0

TABLE 13—TRANSVERSE TESTS OF HEAD OF RAILS WITHOUT FISSURES.

Rail Letter	Rail No.	Tens. Str. lbs. sq. in	Elongation Per cent.	Red. Area Per cent.
C	6	flaw	....	....
"	13	128900	3	3.6
"	16	128900	3	5.1
"	28	123800	4	2.2
"	30	130900	2	1.8
"	33	128400	2	....
"	36	flaw	....	....
	41	flaw	....	....
	Average..........	128180	2.8	3.2
D	1	122300	3	4.8
"	29	116500	3	3.0
"	34	86800	2	1.3
"	37	129500	2	3.2
"	47	132800	5	7.3
"	48	122900	4	4.6
	Average..........	118467	3.2	4.0
E	5	114600	4	5.2
"	8	122800	3	8.6
"	11	123100	3.5	2.0
"	12	120000	2.5	3.0
"	18	123000	2	4.0
"	20	120800	6	7.2
"	21	127900	2.5	4.7
"	23	124400	6	7.0
"	27	120800	6	2.8
"	31	120800	7	4.0
"	32	125300	5	3.0
"	35	113640	4	3.9
"	44	124800	6	5.5
"	46	109600	2	2.0
	Average..........	120824	4.2	4.5
Average of all.....	....	121730	3.7	4.2

TABLE 14—AVERAGE RESULTS OF TRANSVERSE TESTS OF HEAD.

Rail Letter	Tens. Str. lbs. square in.	Elongation Per cent..	Red. Area. Per cent.
Rails with Fissures			
C	129038	3.3	3.9
D	123600	1.8	2.0
Average..............	126707	2.6	3.0
Rails without Fissures			
C	128180	2.8	3.2
D	118467	3.2	4.0
E	120824	4.2	4.5
Average..............	121730	3.7	4.2
General Average......	122818	3.5	3.9

SULPHUR PRINTS.

A sulphur print was made of a cross-section prepared from near the middle of each rail. Examined this way, the rails showed a more or less distinct structure which varied according to the ingot position of the rail, as illustrated in Figs. 10 to 13, inclusive, which show a sample of the structure of each rail of the ingot, namely, B, C, D and E. The A rail is missing, as we had none. The B and C rails show a great many dark spots, indicating points of sulphur concentration; in the head of the B rail they occur largely as a band, while in the head of the C rail they are more scattered. They also occur scattered in the D rail, but less numerous. The E rail shows only a few such spots. The D and E rails show lighter areas in the interior than in the outer parts of the section, which represent regions of softer metal; that is, they show soft centers with lower carbon, phosphorus and sulphur, which is a normal condition in the lower rails of the ingot.

The sulphur prints of the heads only of the other 46 rails are reproduced in Figs. 14 to 18, inclusive, grouped by ingot positions of the rails and arranged numerically within the group. The small figures in the lower right hand corner of the section show the serial number and the ingot position of the rail. It will be noted that sulphide spots, displaying local segregations of sulphur, occur in most of the B, C and D rails more or less extensively, while the E rails are mostly free from them.

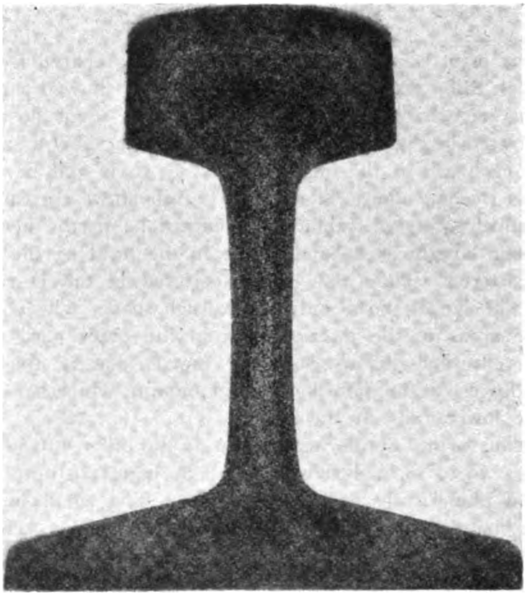

FIG. 10—REPRODUCTION OF SULPHUR PRINT OF REPRESENTATIVE B RAIL

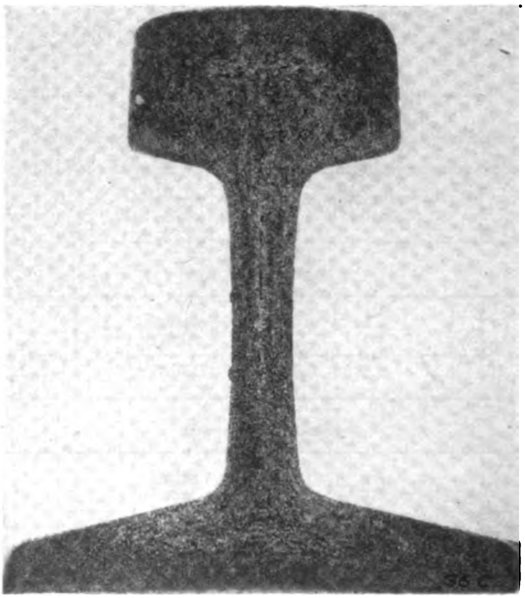

FIG. 11—REPRODUCTION OF SULPHUR PRINT OF REPRESENTATIVE C RAIL.

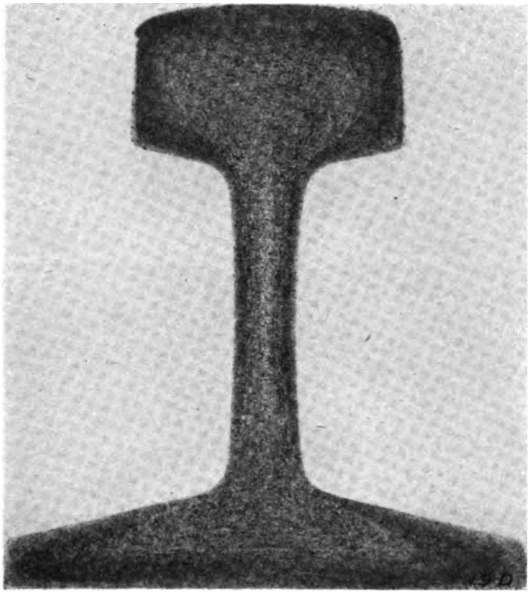

FIG. 12—REPRODUCTION OF SULPHUR PRINT OF REPRESENTATIVE D RAIL.

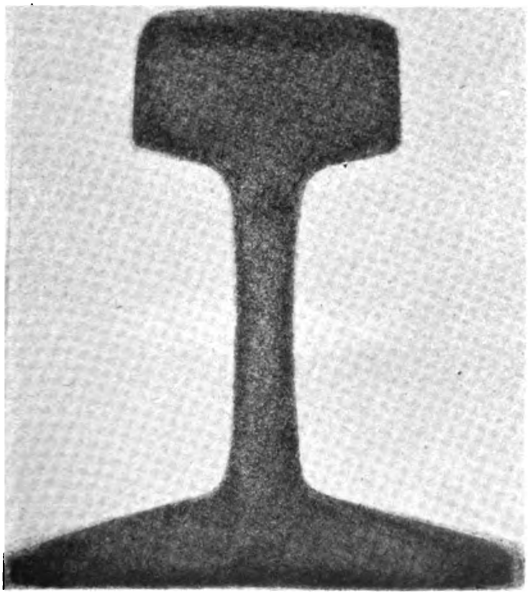

FIG. 13—REPRODUCTION OF SULPHUR PRINT OF REPRESENTATIVE E RAIL.

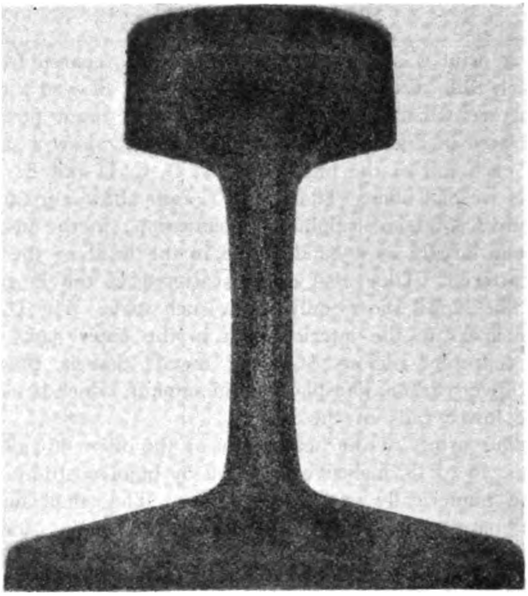

FIG. 10—REPRODUCTION OF SULPHUR PRINT OF REPRESENTATIVE B RAIL

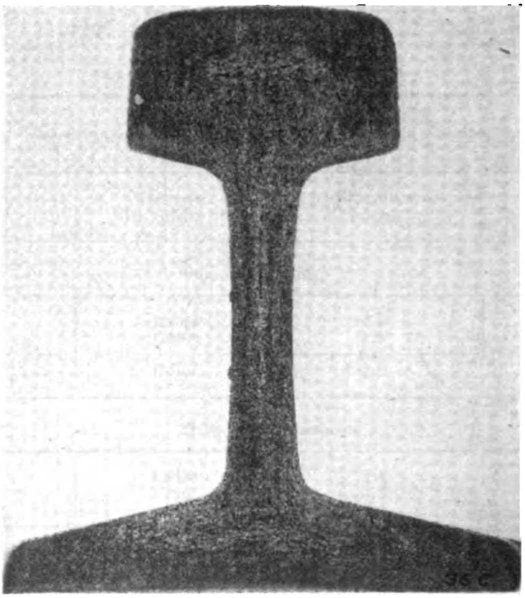

FIG. 11—REPRODUCTION OF SULPHUR PRINT OF REPRESENTATIVE C RAIL.

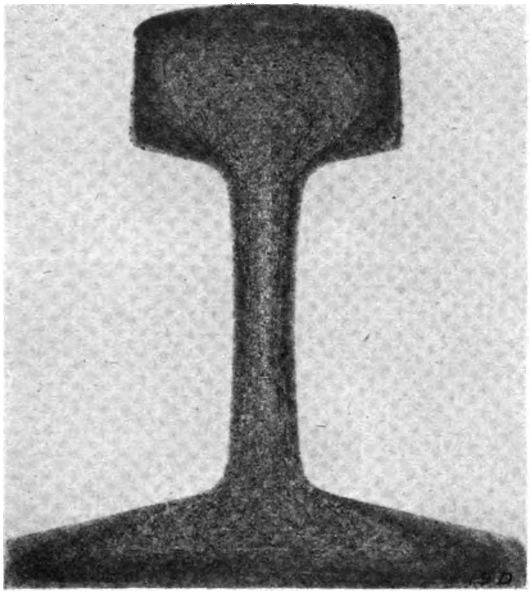

FIG. 12—REPRODUCTION OF SULPHUR PRINT OF REPRESENTATIVE D RAIL.

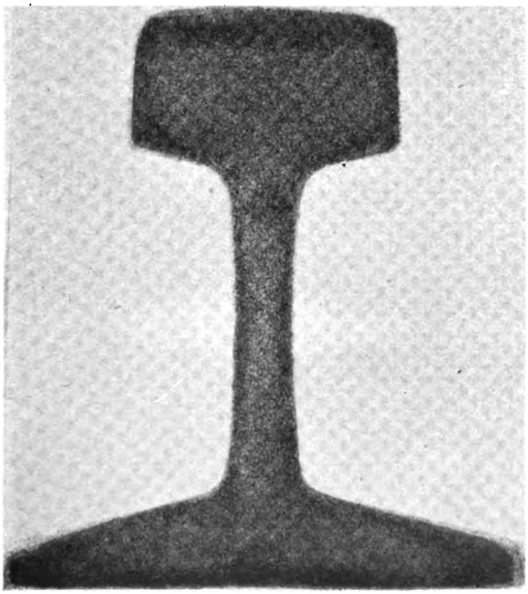

FIG. 13—REPRODUCTION OF SULPHUR PRINT OF REPRESENTATIVE E RAIL.

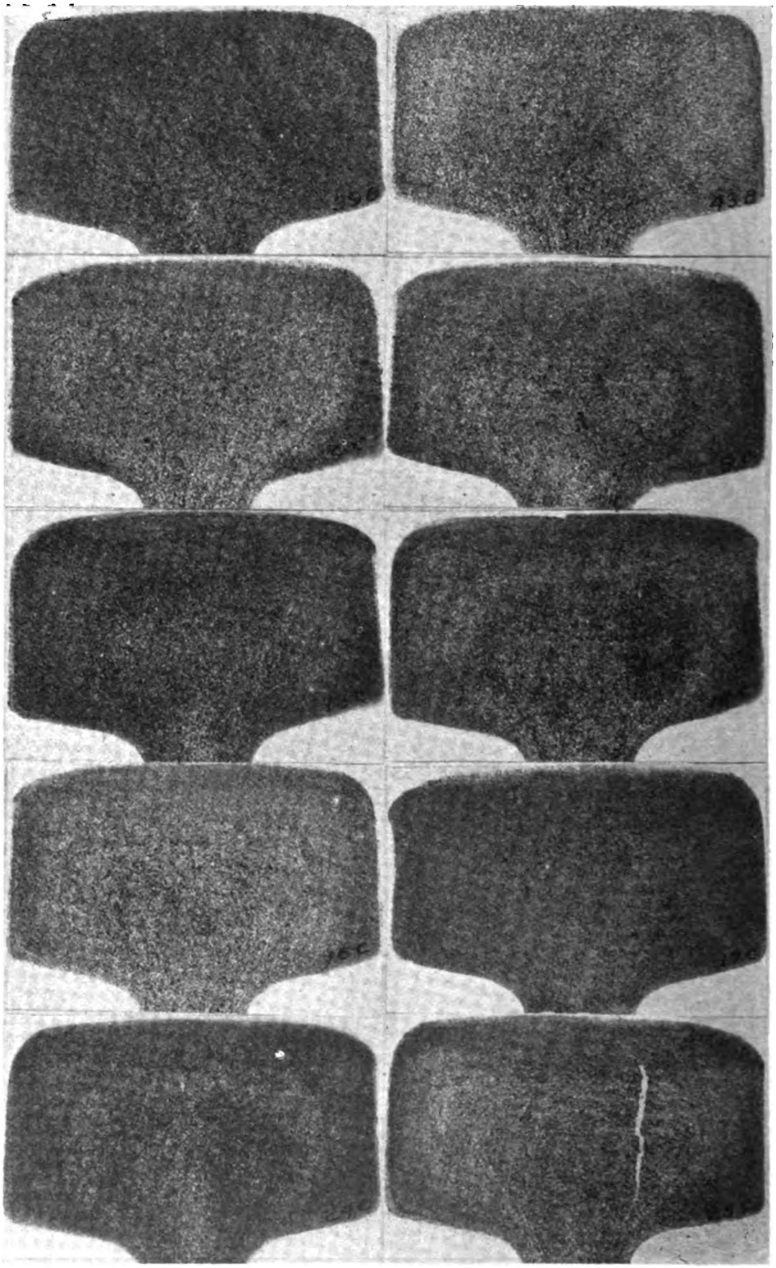

Fig. 14—Reproductions of Sulphur Prints of Heads of B and C Rails.

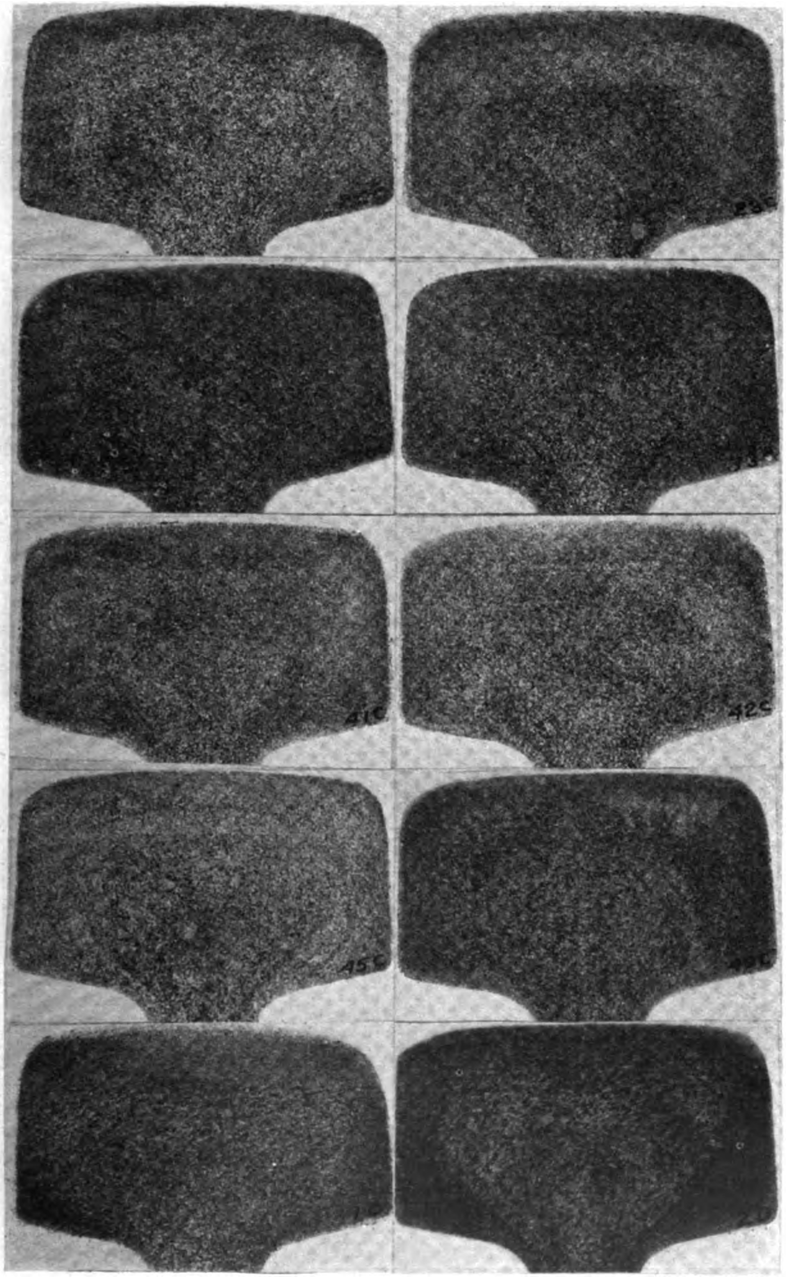

FIG. 15—REPRODUCTIONS OF SULPHUR PRINTS OF HEADS OF C AND D RAILS

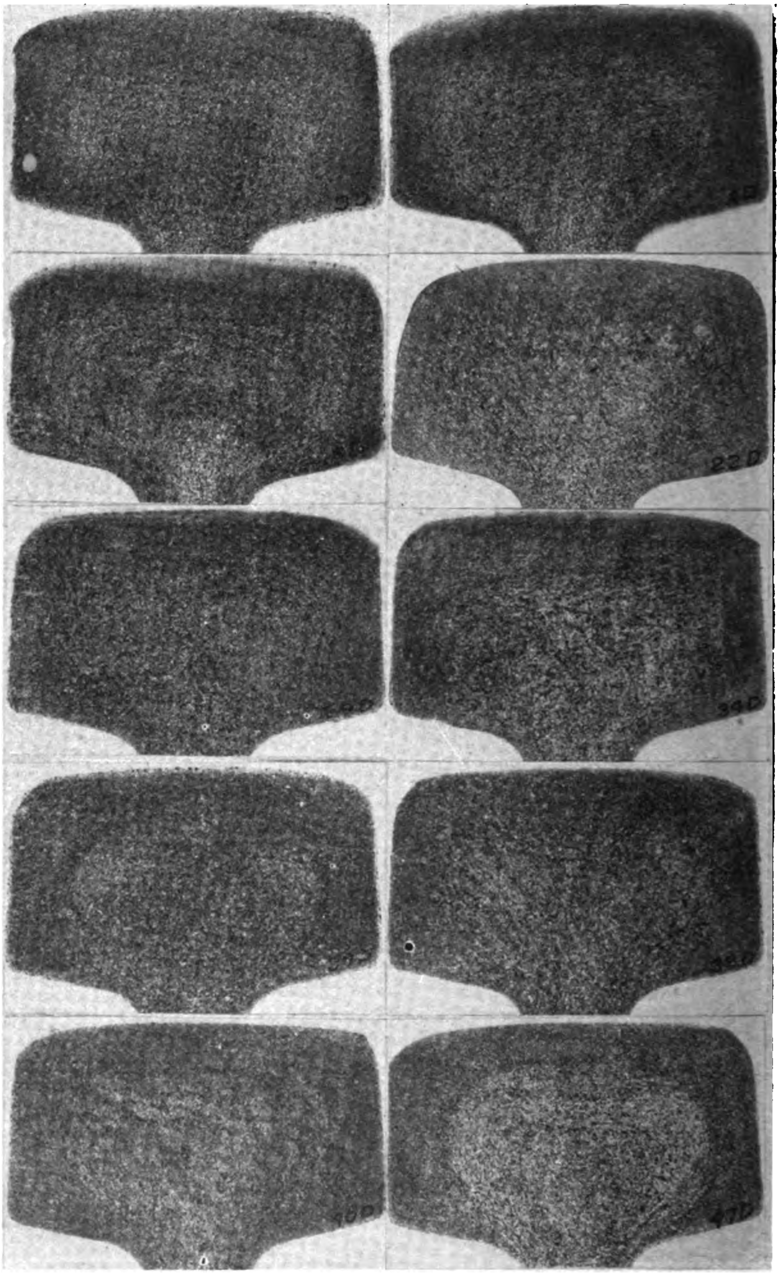

FIG. 16—REPRODUCTIONS OF SULPHUR PRINTS OF HEADS OF D RAILS.

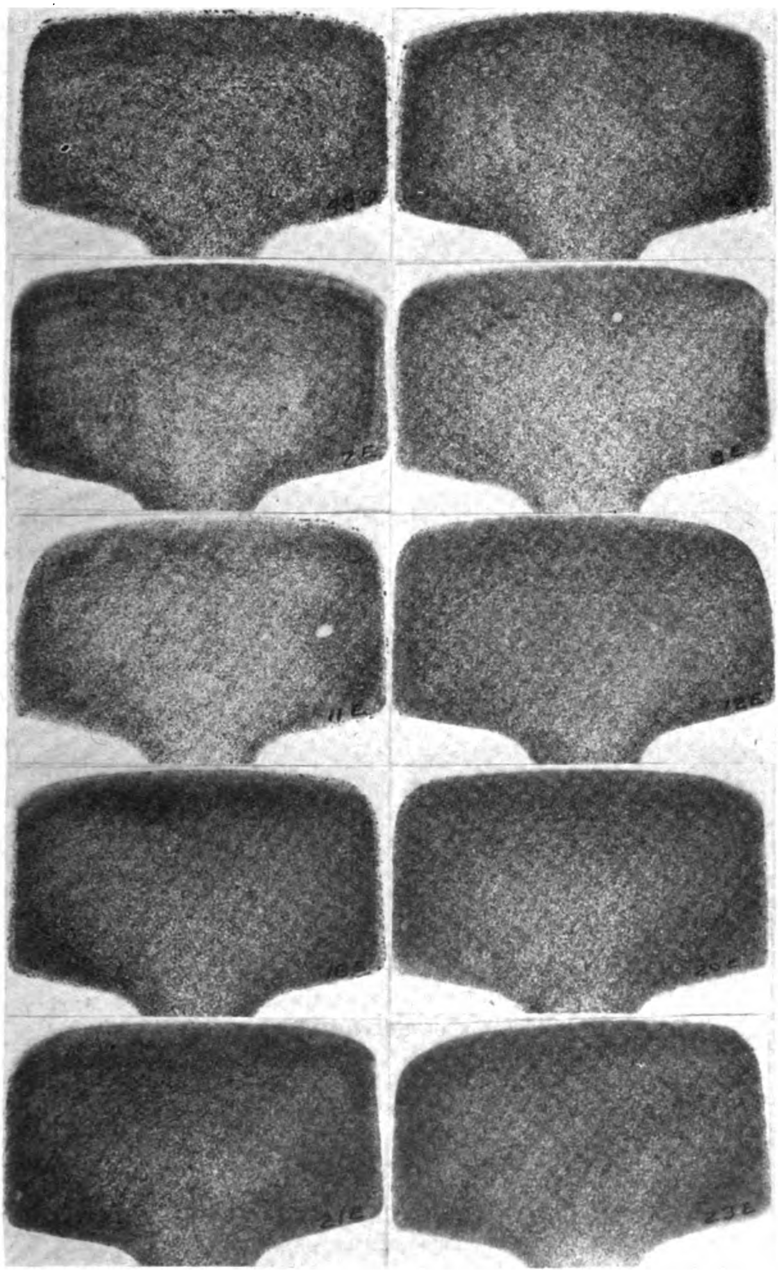

Fig. 17—Reproductions of Sulphur Prints of Heads of D and E Rails.

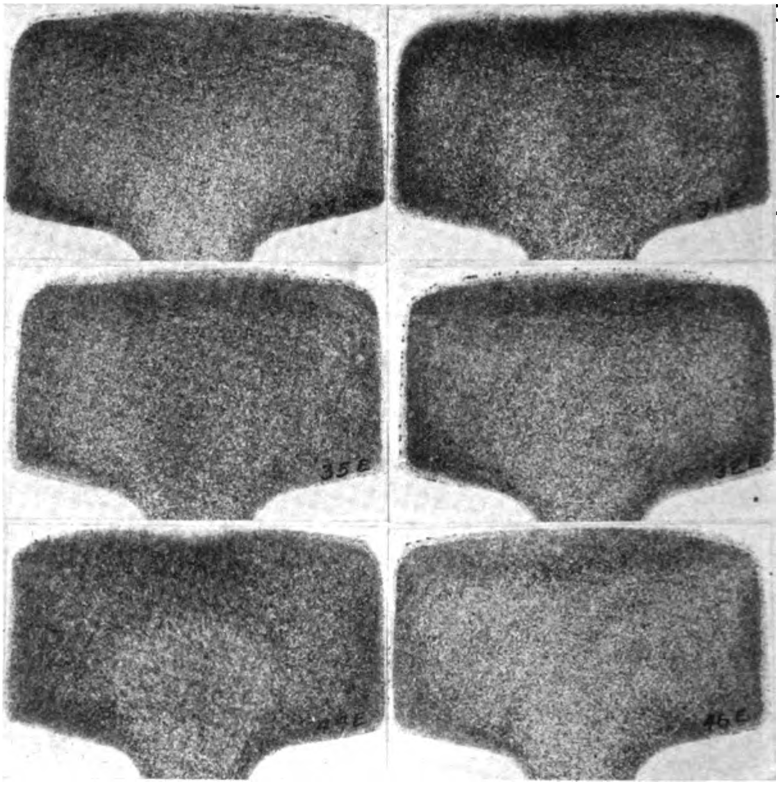

FIG. 18--REPRODUCTION OF SULPHUR PRINTS OF E RAILS.

MICROSCOPIC TESTS.

For examination by means of the microscopic, samples were selected from eight rails as representative of the lot, two from each of the ingot positions B, C, D and E. One each of the C, D and E rails was one in which fissures were found, and the other was one in which fissures were not found. As there were only a few B rails and no fissures were found in them, the two B rails selected, of course, had shown no fissures. The rails selected were as follows:

B rails—Nos. 39 and 43.
C rails—No. 17 with fissure, No. 9 without fissure.
D rails—No. 2 with fissure, No. 22 without fissure.
E rails—No. 7 with fissure, No. 8 without fissure.

Through the kindness of Mr. A. Thompson, General Manager, the organization and equipment of the Titanium Alloy Manufacturing Com-

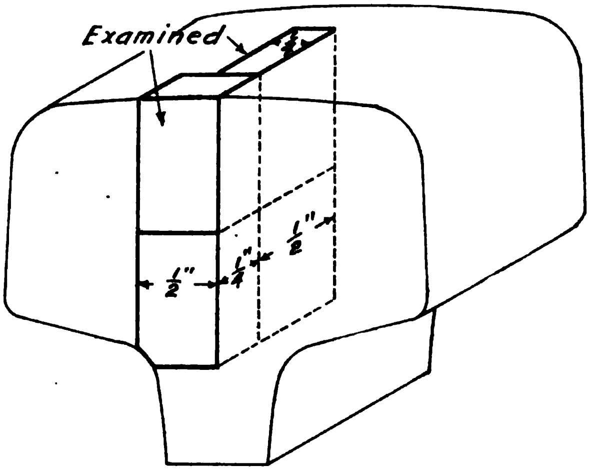

FIG. 19—DIAGRAM OF LOCATIONS OF SAMPLES FOR MICROSCOPIC EXAMINATION.

pany, Niagara Falls, N. Y., were made available for this microscopic work, and the writer wishes also to acknowledge the advice given by Mr. Geo. F. Comstock, Metallographist, and his care and skill in doing the metallographic work, which was done at the laboratory of the Titanium Alloy Manufacturing Company at Niagara Falls.

The metal in the rail head was examined both transversely and longitudinally, the samples being cut out as shown in Fig. 19. As indicated, a transverse section one-half inch wide was cut from the top to the bottom of the head adjacent to the center line, and, for convenience in polishing, this was cut into two parts. Next to this a similar but longitudinal section was cut and the surface examined was the plane cutting the

vertical center line of the transverse section. The longitudinal section was also cut into two parts for convenience of polishing. The surfaces were examined as polished and also after etching with picric acid to determine the grain structure. They were then repolished and etched with Stead's cupric chloride reagent to note the phosphorus distribution.

The method of polishing consisted of first grinding the specimens on the flat side of a fine grained cup wheel and then dry grinding on disks covered successively with No. 1, No. 0 and No. 00 emery paper. The polishing was then continued with alundum powder No. 65 F suspended in water on a disk covered with duck and finally finished with rouge suspended in water on a disk covered with broadcloth. Stead's reagent was made as described by Stead in a paper on "Iron, Carbon and Phosphorus" before the British Iron and Steel Institute in 1915 and consisted of the following:

Cupric chloride	2.5 grams
Magnesium chloride	10.0 grams
Hydrochloric acid	5.0 c.c.
Alcohol to make	250.0 c.c.

The first three materials are made into a solution with a small quantity of water and then diluted with alcohol.

Each sample was examined and some photographs were made representative of the conditions found. Examination of the plain surfaces, skillfully polished, showed the nature of the inclusions in the steel and it was found that these consisted of sulphides, slag and alumina. The sulphides consisted mostly of manganese sulphide and these inclusions were found more or less abundantly in all the specimens examined. The most of them were small, but some of the inclusions were larger in diameter and drawn out into threads. These were apt to occur in groups, forming "streaks" in the steel, which would show as a large, dark soft spot on a sulphur print. The appearance in longitudinal section, of some of the larger manganese sulphide inclusions found, are illustrated in Fig. 20, showing B rail number 39 at the lower part of the head; Fig. 21, showing C rail number 9 at 15/16 inch below the top of the head, and Fig. 22, showing D rail number 22 at 13/16 inch below the top of the head, all unetched and magnified 200 diameters.

Slag or silicate inclusions have much the same appearance, but are apt to be larger in diameter. They are distinguished from manganese sulphide by their dark color in the unetched polished surface, while the sulphides are light in color. A large slag streak found in E rail number 8 at 11/16 inch below the top of the head is shown in Fig. 23. A surface showing both sulphide and slag inclusions is illustrated in Fig. 24, which shows B rail number 43 at ⅜ inch below the top of the head.

Alumina occurs as angular unfused particles and in Fig. 25 a longitudinal streak of alumina particles is shown that were found in the lower part of the head of B rail number 39. The alumina occurred mostly

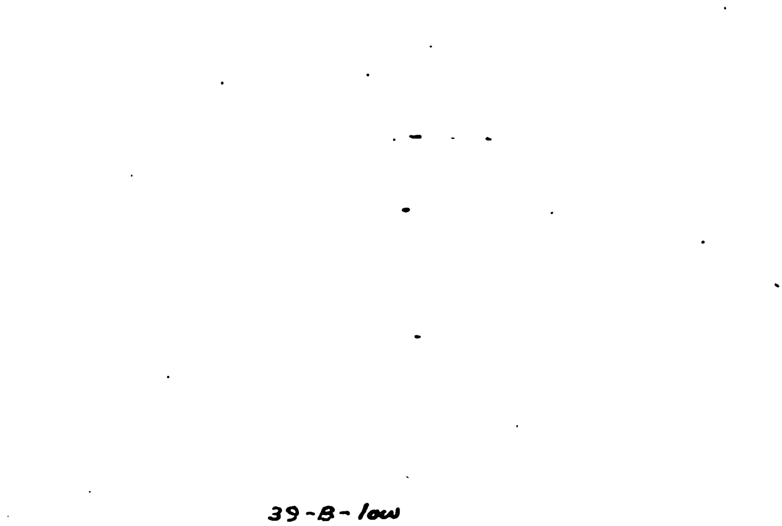

FIG. 20—POLISHED SURFACE OF LONGITUDINAL SECTION OF INTERIOR OF HEAD OF B RAIL NUMBER 39, MAGNIFIED 200 DIAMETERS, SHOWING MANGANESE SULPHIDE INCLUSIONS.

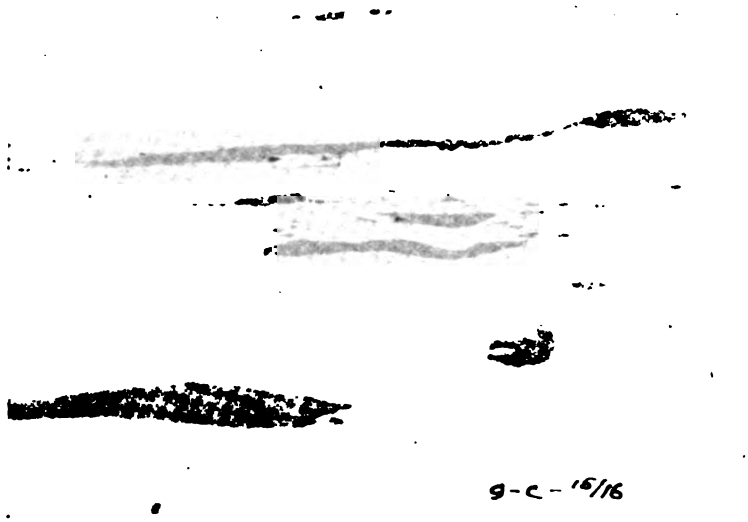

FIG. 21—POLISHED SURFACE OF LONGITUDINAL SECTION OF INTERIOR OF HEAD OF C RAIL NUMBER 9, MAGNIFIED 200 DIAMETERS, SHOWING MANGANESE SULPHIDE INCLUSIONS.

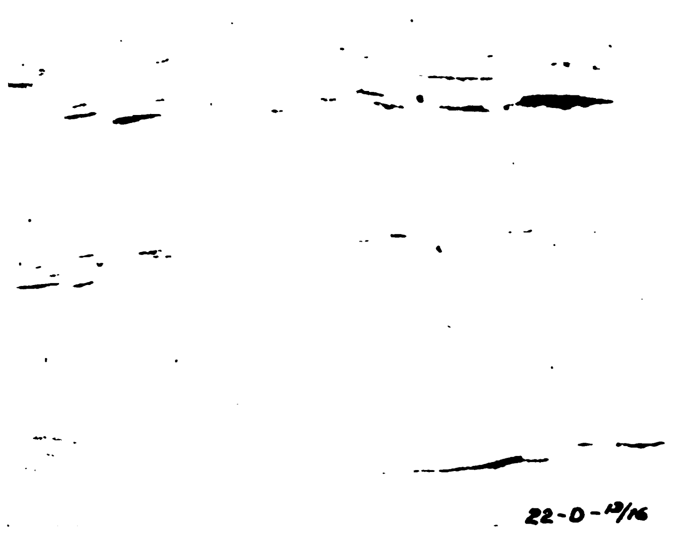

FIG. 22—POLISHED SURFACE OF LONGITUDINAL SECTION OF INTERIOR OF HEAD OF D RAIL NUMBER 22, MAGNIFIED 200 DIAMETERS, SHOWING MANGANESE SULPHIDE INCLUSIONS.

FIG. 23—POLISHED SURFACE OF LONGITUDINAL SECTION OF INTERIOR OF HEAD OF E RAIL NUMBER 8, MAGNIFIED 200 DIAMETERS, SHOWING SLAG INCLUSIONS.

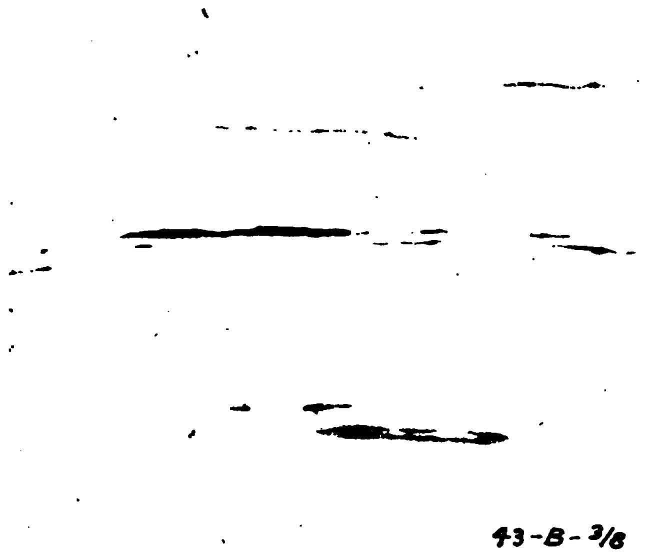

Fig. 24—Polished Surface of Longitudinal Section of Interior of Head of B Rail Number 43, Magnified 200 Diameters, Showing Sulphide and Slag Inclusions.

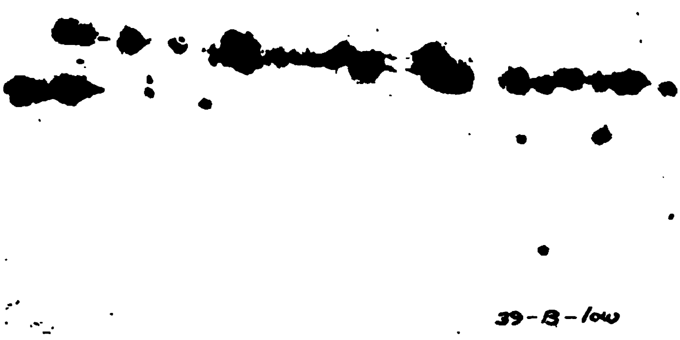

Fig. 25—Polished Surface of Longitudinal Section of Interior of Head of B Rail Number 39, Magnified 200 Diameters, Showing Alumina Inclusions.

Fig. 26—Polished Surface of Cross Section of Interior of Head of B Rail Number 43, Magnified 200 Diameters, Showing Sulphide and Slag Inclusions.

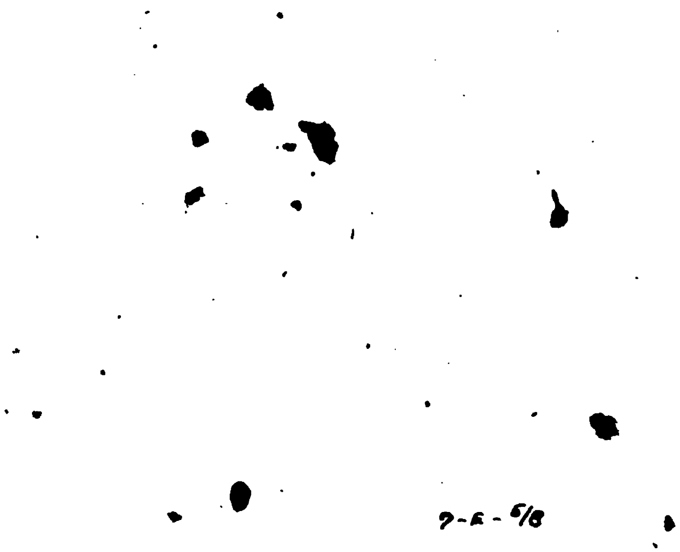

Fig. 27—Polished Surface of Cross Section of Interior of Head of E Rail Number 7, Magnified 200 Diameters, Showing Alumina Inclusions.

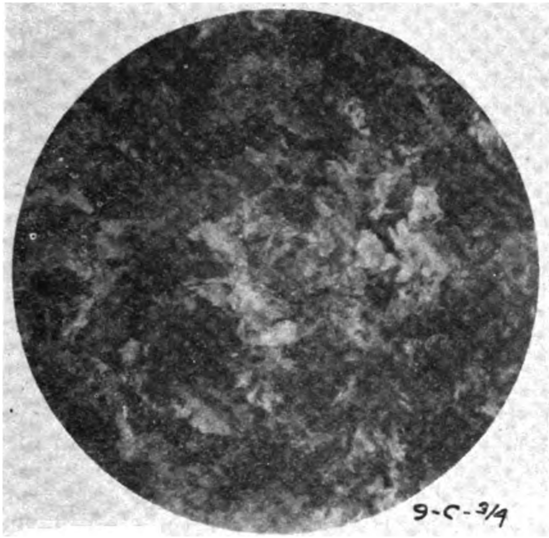

FIG. 28—ETCHED CROSS SECTION OF INTERIOR OF HEAD OF C RAIL NUMBER 9. MAGNIFIED 100 DIAMETERS, SHOWING EUTECTOID STRUCTURE.

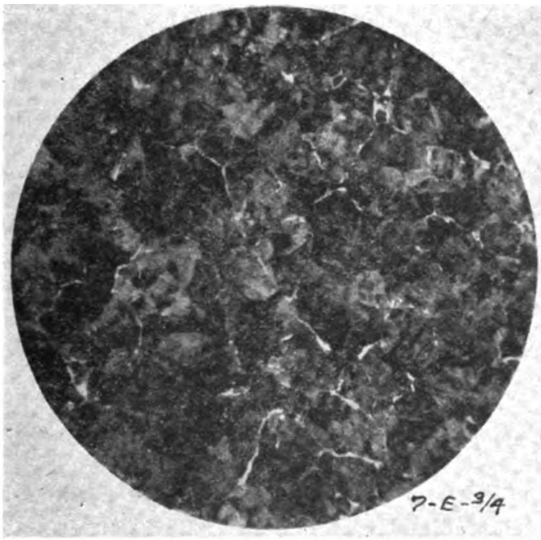

FIG. 29—ETCHED CROSS SECTION OF INTERIOR OF HEAD OF E RAIL NUMBER 7, MAGNIFIED 100 DIAMETERS, SHOWING A LITTLE FERRITE NETWORK.

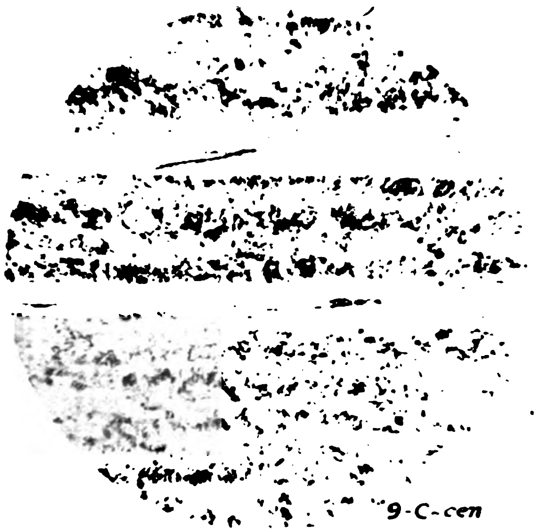

FIG. 30—LONGITUDINAL SECTION OF INTERIOR OF HEAD OF C RAIL NUMBER 9, ETCHED WITH COPPER CHLORIDE, MAGNIFIED 20 DIAMETERS.

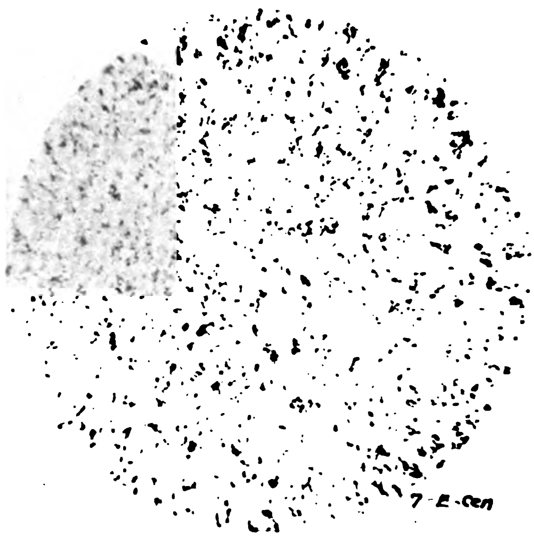

FIG. 31—CROSS SECTION OF INTERIOR OF HEAD OF E RAIL NUMBER 7, ETCHED WITH COPPER CHLORIDE, MAGNIFIED 20 DIAMETERS.

as separate particles even in longitudinal sections, but in this case they occurred as a longitudinal series or streak.

The appearance of the sulphide enclosures in transverse section is illustrated in Fig. 26, showing the unetched polished surface of B rail number 43 at ⅜ inch below the top of the head. The numerous light spots show the manganese sulphide and the few dark spots show the slag or silicate in cross section. Alumina enclosures in cross section are illustrated in Fig. 27, showing E rail number 7 at ⅝ inch below the top of the head. It is interesting to note the larger angular enclosures which show the light colored crystals of alumina partly eroded away in the polishing so as to make them stand as islands in their cavities. The small light spots of manganese sulphide are also numerous.

Representative illustrations of the grain structure of the steel in the interior of the head as brought out by picric acid etching, are given in Fig. 28, showing C rail number 9 at ¾ inch below the top of the head and Fig. 29, showing E rail number 7 also at ¾ inch below the top of the head. These show transverse sections magnified 100 diameters. The former shows a eutectoid structure, and the latter, where the carbon is lower, shows a little ferrite network.

An illustration of a longitudinal section etched with copper chloride is given in Fig. 30 of C rail number 9 near the center of the head, magnified 20 diameters. A similar illustration of a transverse section is given in Fig. 31 of E rail number 7, also near the center of the head. The higher the phosphorus the more resistant it is to etching by this reagent, and therefore the lighter colored parts in the illustrations indicate the presence of higher phosphorus. The longitudinal banding indicates an uneven absorption of the phosphorus, but as very little work has been done with this reagent on rails, we are unable to say to what extent this condition is normal in rails.

To sum up the results of the microscopic tests, it may be said that the interior of the head contained numerous non-metallic inclusions consisting of sulphides, slag and alumina. While sulphide inclusions occur to some extent in all steel containing sulphur, the slag and alumina and excessive sulphide inclusions are indicative of defective metallurgical practice. In the interior of the head, the non-metallic inclusions in some cases were found to be so abundant as to render the steel "crumby" and somewhat akin to wrought iron with its slag streaks.

SUMMARY.

1. Tests were made of a heat of rails on the Baltimore & Ohio Railroad, which was removed from service on account of four rails breaking and showing interior fissures. Fifty rails were gathered up and sent to the B. & O. R. R. Laboratory at Baltimore, where they were subjected to drop tests, chemical analyses, longitudinal and transverse tensile tests and sulphur printing. Microscopic tests were also made at the labora-

tory of the Titanium Alloy Manufacturing Company at Niagara Falls, N. Y.

2. Drop tests were made of the rails to disclose the fissures present. Numerous fissures were found, mostly of the compound type, consisting of a horizontal fissure that has worked out from a longitudinal streak in the interior of the rail head, and with a transverse branch issuing from the horizontal part. The fissures were more numerous in the rails that had been in the heavier service and less numerous in the bottom rail of the ingot.

3. The average composition of the steel in the rails was as follows: C, .65; S, .053; P, .023; Mn, .78; Cr, .35; Ni, .42; Si, .15. The sulphur was a little higher than usual in rail steel. There was a fairly uniform distribution of the elements in most of the rails, and the rails with fissures were chemically about the same as those without fissures.

4. Two samples for longitudinal tensile test were taken from each rail, one from an upper corner of the head or O position and the other from the interior of the head or M position.

5. The rails showed good longitudinal tensile strength and ductility in both the outer and interior parts of the head. The rails with fissures showed about the same tensile properties as those in which fissures were not found. In the interior of the head the tensile strength decreased and the elongation increased downward of the ingot; in other words, the interior metal of the ingot became softer downward of the ingot.

6. Transverse tensile tests were made of samples across the middle of the head. Most of the rails showed but little cross stretch with fractures showing streaks that were longitudinal of the rail in the interior of the head.

7. Sulphur prints were made of each rail. These showed the "sulphur spots" (indicating local segregations of sulphur) frequent in the upper part of the ingot. The spots occurred more or less in all rails of the ingot except that the E or bottom rail showed only a few of them.

8. The microscopic tests showed the presence of non-metallic inclusions of sulphides, slag and alumina. They were mostly scattered, but in places were also collected into groups forming the streaks found in the fractures or the spots seen in the sulphur prints.

9. In conclusion, it may be said that chemically the material was a little high in sulphur, but in general was free from segregation. Physically, the metal of the head showed good tensile properties in a longitudinal direction, but transversely was low in ductility. The interior of the head contained streaks of non-metallic material consisting of sulphides, slag and alumina. These rendered the metal in the head somewhat akin to wrought iron, in that it would stretch well lengthwise, but was "crumby" when subjected to cross stretch, breaking along a streak.

Appendix E.

RAIL FAILURE STATISTICS FOR 1917

By M. H. Wickhorst, Engineer of Tests, Rail Committee.

This report deals with the statistics of rail failures collected for the year ending October 31, 1917, furnished by the railroads of the United States and Canada, in response to a circular sent out by the American Railway Association. The information furnished by each railroad showed the number of tons laid of each year's rolling from each mill, the equivalent number of track miles, and the total number of failures that occurred in each year's rolling from the date laid until October 31, 1916.

The failures were divided into four classes; namely, head, web, base and "broken." They were reported by the railroads on American Railway Engineering Association form 408 as revised in 1915. (See Manual for 1915, page 104.) The reports cover rollings for 1912 and succeeding years, and the ages of the rollings would average in track about the years shown below:

1912	5 years	1915	2 years
1913	4 years	1916	1 year
1914	3 years	1917	Several months

The tonnages represented by the statistics in this report are shown below:

Year Rolled	*Bessemer*	*Open-Hearth*	*Total*
1912	211,125	1,308,601	1,519,726
1913	154,412	1,647,659	1,802,071
1914	60,654	1,073,098	1,133,752
1915	12,141	1,075,111	1,087,252
1916	41,737	1,219,694	1,261,431
1917	14,613	681,669	696,282

The equivalent track miles are as follows:

Year Rolled	*Bessemer*	*Open-Hearth*	*Total*
1912	1,518.71	9,259.97	10,778.68
1913	1,107.32	11,419.28	12,526.60
1914	431.39	7,388.40	7,819.79
1915	90.89	7,253.76	7,344.65
1916	319.44	8,213.09	8,532.53
1917	108.22	4,605.54	4,713.76

It will be noted that in recent years the Bessemer steel has formed only a small part of the rail rolled as covered by the returns in this report. The failures were tabulated with reference particularly to the performance of the rails made by the different mills and were classified successively in the following order: Kind of steel (Bessemer or open-

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hearth), mill, year rolled, weight per yard, section and railroad. The totals were figured for the groups by the year rolled.

Lots of less than 1000 tons (that is, less than 1000 tons in any one year's rolling for a railroad) were excluded from the tabulation, as they would unnecessarily extend the tables and not materially change the group totals and averages. The method of compiling the statistics was to make prints (generally blue-line white prints) of the reports submitted by the different railroads after seeing that all the lines were fully filled out, and then cutting them up along the horizontal lines with a large card cutter or trimming board. The strips constituted the units in the tables, and after sorting in suitable order and collecting into the desired groups, the information was transcribed on a typewriter into tables, from which zinc plates were made for printing in this report.

The writer wishes to acknowledge the careful work of Mr. A. M. Van Auken, who made the calculations and tables in this report.

FAILURES CLASSIFIED BY MILLS.

The detail tabulations by mills and years rolled are given in Table 7, sheets 1 to 15, inclusive. A condensed table showing the failures of each year's rolling of each mill is given in Table 1. First, it is interesting to note from this table, the comparative performance of Bessemer and open-hearth rails. Figuring the failures per 100 track miles of open-hearth rails as 100 for each of the years 1912, 1913, 1914 and 1915, the relative failures of Bessemer rails, together with the failures per 100 track miles, are shown below:

FAILURES OF BESSEMER AND OPEN-HEARTH COMPARED.

Year Rolled	*Years Service*	*Failures Per 100 Track Miles*		*Comparative Failures*	
		Open-Hearth	*Bessemer*	*Open-Hearth*	*Bessemer*
1912........	5	102.7	134.1	100	131
1913........	4	68.5	79.7	100	116
1914........	3	30.8	70.2	100	228
1915........	2	19.0	19.8	100	104

The Bessemer rails showed more failures per 100 track miles, but, as they were in general in less severe service, the actual difference in the same service would undoubtedly have been greater.

The failures per 100 track miles for each of the mills classified by kind of steel and year rolled are shown graphically in Fig. 1.

The average weights per yard, compiled from the tonnages used in this report, are shown in Table 6. It will be noted that the Bessemer rail tends to become lighter in weight and the open-hearth to become heavier, due presumably to replacement of Bessemer rail for the more important service by open-hearth rail.

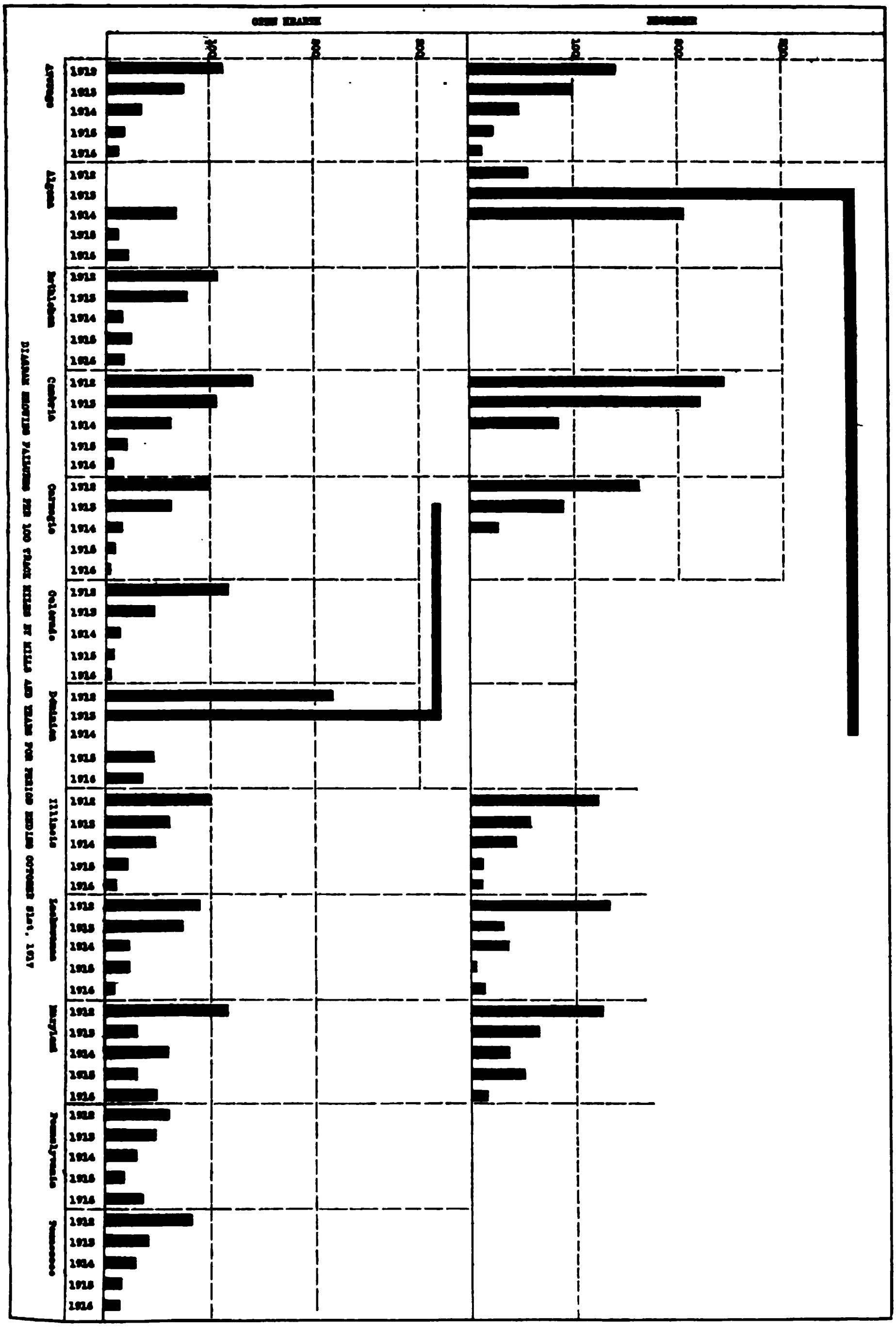

FIG. 1—RAIL FAILURES BY MILLS AND YEARS ROLLED.

The results shown by these statistics are in general consistent among themselves, but inconsistencies occur in the comparison of some of the rollings from year to year, due to differences in the railroads that have reported on such rollings from year to year. Since these statistics were started they have become more complete by more roads sending in reports and by the reports being made out in better form. But also in a small number of cases roads have failed to make reports on rollings that had previously been reported on. In this way the rails shown for any year's rolling by a mill may not be the same rails that had been previously reported on. Thus it may happen that the failures per 100 track miles in a group may show less than had been shown in a previous report for the same group for a less period of service. Although the general trend of the rail failures is probably satisfactorily shown, it is necessary for the above reasons to exercise care in using the smaller groupings.

RANKING OF MILLS.

In order to show more conveniently the relative number of failures from each of the mills and to show the ranking of the mills as regards the failure performance of the rails rolled by them, Table 3 has been prepared. Taking the average of failures per 100 track miles of all the mills in each group (Bessemer and open-hearth), in any year's rolling as 100, the relative number of failures of each of the mills is shown for the years 1912, 1913, 1914 and 1915. The later rollings are not included because of being too young. The rank of each mill is shown for each year's rolling.

COMPARISON WITH PREVIOUS YEARS.

One important purpose of these statistics is to enable comparisons to be made of the performance of rail rolled from year to year, and Tables 4 and 5 are given, showing the general records taken from the reports for the years 1913 to 1917, inclusive, one table for Bessemer rails and the other for open-hearth rails. The final comparison is made on the basis of five years' service, but before closing the record of any year's rolling, a comparison can be made on the performance of a less number of years' service. The records are closed for the rollings for 1908 to 1912, inclusive, and it will be noted that the average of the Bessemer rail from all the mills showed reductions in the number of failures in the successive years. The open-hearth rail also showed reductions in the number of failures in successive years, except that the 1911 rail showed a somewhat larger amount than did the rail rolled in the year previous.

A summary of the general results as given in the reports for 1913 to 1916 and this report is submitted herewith as Table 2. The average failures per 100 track miles of the rollings for the several years, including both Bessemer and open-hearth rails, is given in the following table:

Year Rolled	Years Service 0	1	2	3	4	5
1908.........	....	....	....	....	....	398.1
1909.........	....	....	....	....	224.1	277.8
1910.........	....	....	....	124.0	152.7	198.5
1911.........	....	....	77.0	104.4	133.3	176.3
1912.........	....	28.9	32.1	49.3	78.9	107.1
1913.........	2.0	12.5	25.8	44.8	69.5	....
1914.........	1.2	8.2	19.8	32.9	....	....
1915.........	0.7	8.9	19.0	....	....	....
1916.........	1.6	11.8	....	....	....	....
1917.........	5.3	....	....	....	....	....

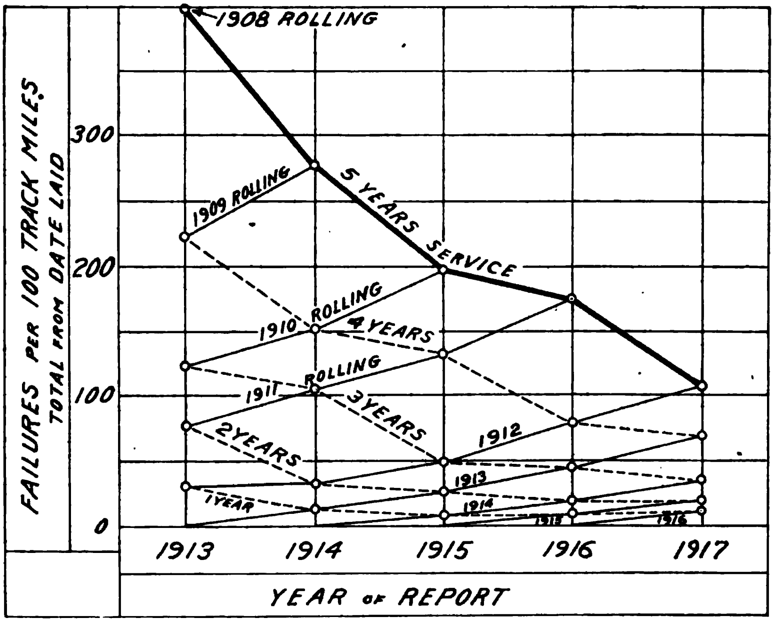

FIG. 2—FAILURES OF RAILS. THE HEAVY SOLID LINE SHOWS THE FAILURES AFTER FIVE YEARS' SERVICE FOR THE 1908 TO 1912 ROLLINGS. THE DOTTED LINES SHOW THE FAILURES FOR LESS YEARS' SERVICE. THE LIGHT SOLID LINES SHOW THE ACCUMULATED FAILURES FOR SUCCESSIVE YEARS, EACH LINE REPRESENTING A CERTAIN YEAR'S ROLLING.

These results are also shown diagrammatically in Fig. 2. It will be noted that the 1908 to 1912 rollings show successively decreased numbers of failures compared on a basis of five years' service, and the rollings for 1913 and 1914 also show successively decreased failures when com-

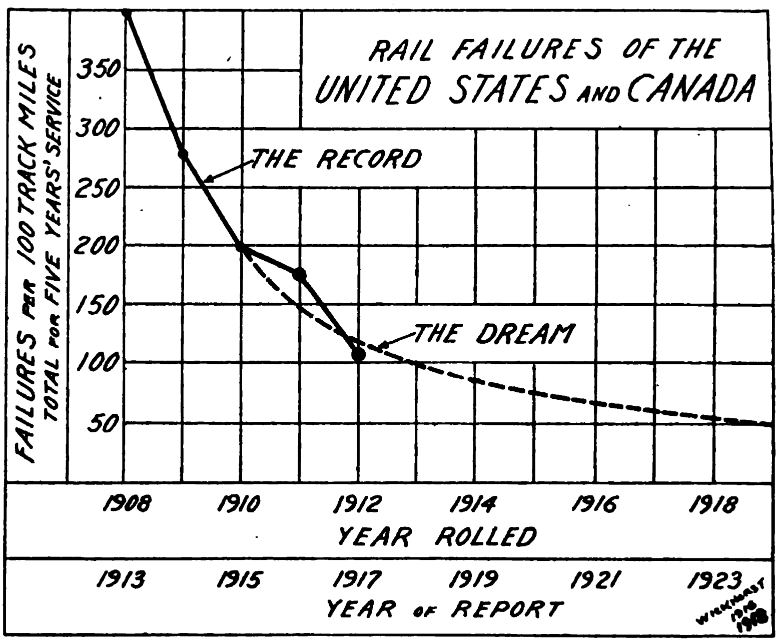

FIG. 3—GENERAL DIAGRAM OF RAIL FAILURES.

pared on a shorter period of service. The more recent or "war-time" rollings, however, are not starting out so well, but what the final performance will be can only be told after they have been in service a sufficient length of time.

In this connection, the writer wishes to call attention to a diagram submitted with a paper,* entitled "The Rail Failure Situation," on which was shown the completed rail failure record taken from the reports for 1913, 1914 and 1915, and on which also was projected what we would like the record to be in future reports. This diagram is reproduced herewith as Fig. 3 with the insertion of the records from the 1916 and 1917 reports. It will be noted that our "Dream" is thus far coming true, and a study of the performance of the rails for shorter periods of service, indicates that the record will be favorable for another year or two, but when we come to recent rollings, the record may acquire an upward hump. It may be that due to war conditions the standard of quality of both the manufacture of the rails and the maintenance of the track has not been upheld. It behooves the railroads to watch closely the material going into rails and the condition of the track in order not to have too large a crop of rail breakages blamable indirectly to the war.

*Proceedings American Railway Engineering Association, Vol. 18, 1917, p. 1219.

Table 1

SUMMARY SHOWING TRACK MILES OF RAIL, TOTAL FAILURES AND FAILURES PER 100 TRACK MILES

GROUPED BY MILLS AND YEARS

Mill	1912			1913			1914			1915			1916			1917		
	Trk Mls of Rail Laid	Failures		Trk Mls of Rail Laid	Failures		Trk Mls of Rail Laid	Failures		Trk Mls of Rail Laid	Failures		Trk Mls of Rail Laid	Failures		Trk Mls of Rail Laid	Failures	
		Total	Per 100 Trk Mls		Total	Per 100 Trk Mls		Total	Per 100 Trk Mls		Total	Per 100 Trk Mls		Total	Per 100 Trk Mls		Total	Per 100 Trk Mls
BESSEMER RAIL																		
Algoma	8.76	5	57.1	7.96	71	892.0	81.98	169	206.1									
Cambria	89.49	219	244.7	60.44	134	221.7	11.56	10	86.5									
Carnegie	70.06	113	161.3	228.65	209	91.4	77.74	22	28.3									
Illinois	597.01	730	122.3	313.68	180	57.4	95.81	42	43.8	49.45	6	12.1	185.15	21	11.3	58.09	0	0.0
Lackawanna	245.59	326	132.7	121.05	38	31.4	72.45	26	35.9	19.65	1	5.1	29.65	4	13.5	12.35	0	0.0
Maryland	507.80	643	126.6	375.56	251	66.8	91.87	34	37.0	21.79	11	50.5	104.65	17	16.2	37.78	1	2.6
Totals	1518.71	2036	134.1	1107.32	883	79.7	431.39	303	70.2	90.89	18	19.8	319.44	42	13.1	108.22	1	0.9
OPEN HEARTH RAIL																		
Algoma							114.96	77	67.0	397.56	47	11.8	198.66	45	22.7	25.61	38	155.5
Bethlehem	739.15	789	106.8	886.26	685	77.3	544.24	87	16.0	506.79	124	24.5	467.77	83	17.7	405.03	49	12.1
Cambria	571.58	805	140.9	649.77	690	106.2	357.07	221	61.9	332.68	65	19.5	381.55	28	7.3	28.08	4	14.3
Carnegie	627.80	620	98.8	764.77	481	62.9	470.04	78	16.6	752.13	65	8.6	855.86	44	4.9	265.79	4	1.5
Colorado	1682.94	1979	117.6	1284.49	598	46.6	1038.76	146	14.1	1056.79	81	7.7	1305.92	76	5.8	752.25	5	0.7
Dominion	223.49	487	217.9	119.54	629	526.2				73.74	34	46.1	89.69	32	35.7			
Illinois	2168.74	2168	100.0	3239.94	2011	62.1	1508.60	714	47.3	1948.22	426	21.9	2383.22	264	11.1	1381.33	10	0.7
Lackawanna	1114.27	987	88.6	1466.80	1085	74.0	764.22	187	24.5	739.30	176	23.8	948.37	84	8.9	643.01	5	0.8
Lorain	24.94	7	28.1															
Maryland	102.88	114	110.8	474.45	555	117.0	457.87	144	31.5	280.63	169	60.2	329.11	101	30.7	234.79	115	49.0
Pennsylvania	501.50	303	60.4	626.75	296	47.2	261.51	77	29.4	160.02	29	18.1	47.75	17	35.6	61.76	0	0.0
Tennessee	1502.91	1251	83.2	1906.51	795	41.6	1871.14	542	29.0	1005.91	161	16.0	1207.19	188	15.6	809.89	26	3.2
Totals	9259.97	9510	102.7	11419.28	7825	68.5	7388.40	2273	30.8	7255.76	1377	19.0	8215.09	962	11.7	4605.54	250	5.4
SUMMARY																		
Total, Bess	1518.71	2036	134.1	1107.32	883	79.7	431.39	303	70.2	90.89	18	19.8	319.44	42	13.1	108.22	1	0.9
Total, O.H.	9259.97	9510	102.7	11419.28	7825	68.5	7388.40	2273	30.8	7255.76	1377	19.0	8215.09	962	11.7	4405.54	250	5.4
Grand Total	10778.68	11546	107.1	12526.60	8706	69.5	7819.79	2576	32.9	7344.65	1395	19.0	8532.53	1004	11.8	4713.76	251	5.3

Table 2

SUMMARY FROM FIVE YEAR'S REPORTS SHOWING TRACK MILES, TOTAL FAILURES AND FAILURES PER 100 TRACK MILES

SHOWING BESSEMER, OPEN HEARTH AND TOTAL

Service	Five Years			Four Years			Three Years			Two Years			One Year			Several Months		
	Trk Mls of Rail Laid	Failures Total	Failures Per 100 Trk Mls	Trk Mls of Rail Laid	Failures Total	Failures Per 100 Trk Mls	Trk Mls of Rail Laid	Failures Total	Failures Per 100 Trk Mls	Trk Mls of Rail Laid	Failures Total	Failures Per 100 Trk Mls	Trk Mls of Rail Laid	Failures Total	Failures Per 100 Trk Mls	Trk Mls of Rail Laid	Failures Total	Failures Per 100 Trk Mls
FROM 1913 REPORT																		
Year Rolled	1908			1909			1910			1911			1912			1913		
Total Bess.	2068.16	8548	413.3	3065.49	9179	299.4	3991.21	7640	186.9	1973.70	2610	132.2	559.63	325	58.1	430.35	21	4.9
Total O.H.	1133.19	4198	370.5	3275.05	5029	153.6	5868.97	4767	81.3	4562.35	2420	53.0	6546.11	1725	26.3	5418.29	97	1.8
Grand Total	3201.35	12746	398.1	6340.54	14208	224.1	9860.18	12227	124.0	6536.05	5030	77.0	7106.74	2050	28.9	5848.64	118	2.0
FROM 1914 REPORT																		
Year Rolled	1909			1910			1911			1912			1913			1914		
Total Bess	3026.03	11316	373.9	4010.42	8874	221.3	1658.33	2646	159.6	671.91	425	63.3	481.95	140	29.1	141.54	3	2.1
Total O.H.	3671.36	7289	198.5	6014.43	6435	107.1	4438.25	3708	83.5	6938.69	2006	28.9	8293.49	955	11.5	4626.80	53	1.1
Grand Total	6697.39	18605	277.8	10024.85	15309	152.7	6096.58	6354	104.4	7610.60	2431	32.1	8775.44	1095	12.5	4768.34	56	1.2
FROM 1915 REPORT																		
Year Rolled	1910			1911			1912			1913			1914			1915		
Total Bess	4678.46	12344	256.9	2411.10	4441	184.2	1657.33	1108	66.9	998.05	352	35.2	380.02	58	15.1	99.12	0	0.0
Total O.H.	6908.97	10657	154.0	5569.65	6194	111.2	8716.85	4011	46.0	9670.54	2404	24.8	6681.22	531	7.9	4187.14	31	0.8
Grand Total	11587.43	22961	198.5	7980.75	10635	133.3	10374.18	5119	49.3	10668.59	2756	25.8	7061.24	584	8.2	4286.26	31	0.7
FROM 1916 REPORT																		
Year Rolled	1911			1912			1913			1914			1915			1916		
Total Bess.	2198.87	4709	214.1	1448.22	1560	107.7	969.97	583	60.1	452.49	146	32.3	90.39	10	11.1	259.67	3	1.2
Total O.H.	5770.54	9343	161.9	8812.71	6540	74.2	10365.44	4493	44.3	7052.75	1337	18.9	7291.00	646	8.8	5093.04	84	1.7
Grand Total	7969.41	14052	176.3	10260.93	8100	78.9	11335.41	5076	44.8	7505.24	1483	19.8	7381.39	656	8.9	5352.71	87	1.6
FROM 1917 REPORT																		
Year Rolled	1912			1913			1914			1915			1916			1917		
Total Bess.	1518.71	2036	134.1	1107.32	883	79.7	451.39	303	70.2	90.89	18	19.8	319.44	42	13.1	108.22	1	0.9
Total O.H.	9259.97	9510	102.7	11419.28	7823	68.5	7368.40	2273	30.8	7253.76	1377	19.0	8213.09	962	11.7	4605.54	250	5.4
Grand Total	10778.68	11546	107.1	12526.60	8706	69.5	7819.79	2576	32.9	7344.65	1395	19.0	8532.53	1004	11.8	4713.76	251	5.3

Table 3

COMPARISON OF FAILURES FOR THE DIFFERENT MILLS, USING 100 AS THE AVERAGE OF FAILURES OF ALL MILLS FOR EACH YEARS ROLLINGS.								
Mill	1912		1913		1914		1915	
	Relative Failures	Rank	Relative Failures	Rank	Relative Failures	Rank	Relative Failures	Rank
BESSEMER								
Algoma	42.6	1	1119.2	6	293.6	6		
Cambria	182.5	6	278.2	5	125.2	5		
Carnegie	120.3	5	114.7	4	40.3	1		
Illinois	91.2	2	72.0	2	62.4	4	61.1	2
Lackawanna	99.0	4	59.4	1	51.1	2	25.8	1
Maryland	94.4	3	83.8	3	52.7	3	255.0	3
OPEN HEARTH								
Algoma					217.5	10	62.1	3
Bethlehem	104.0	6	112.8	7	51.9	2	129.0	9
Cambria	157.2	9	155.0	8	201.0	9	102.6	6
Carnegie	96.2	4	91.8	5	53.9	3	45.3	2
Colorado	114.5	8	68.0	2	45.8	1	40.5	1
Illinois	97.4	5	90.7	4	153.6	8	115.3	7
Lackawanna	86.3	3	108.0	6	79.5	4	125.3	8
Maryland	107.9	7	170.8	9	102.3	7	316.8	10
Pennsylvania	58.8	1	68.9	3	95.5	6	95.3	5
Tennessee	81.0	2	60.7	1	94.2	5	84.2	4

FAILURES FOR VARIOUS AGES OF RAIL PER 100 TRACK MILES.												
	BESSEMER											
Year Rolled	Years Service						Years Service					
	0	1	2	3	4	5	0	1	2	3	4	5
	Algoma						Cambria					
1908						684.4						134.0
1909					312.3						323.1	325.9
1910				397.7		140.7				207.3	295.4	405.6
1911			342.5						58.1	157.6	254.6	352.7
1912		155.6			11.4	57.1		24.7	118.0	126.3	220.3	244.7
1913				188.0	892.0		0.0	4.0	20.1	157.1	221.7	
1914		21.7	69.5	206.1			0.0	8.6	26.0	86.5		
1915							0.0	15.8				
1916												
1917												
	Carnegie						ILLinois					
1908						416.4						491.2
1909					1050.2	1249.0					146.4	168.8
1910				277.1	361.0	482.1				187.9	196.4	205.9
1911			83.1	125.0	163.1	200.3			110.2	191.3	183.1	205.2
1912		19.2	72.9	141.9	107.1	161.3		44.1	13.1	54.8	90.9	122.3
1913	8.7	15.8	29.8	52.9	91.4		0.0	3.1	28.3	43.9	57.4	
1914	0.0	0.0	18.0	28.3			0.0	20.7	23.5	43.8		
1915							0.0	10.0	12.1			
1916							2.2	11.3				
1917							0.0					
	Lackawanna						Maryland					
1908						466.7						222.9
1909					53.6	104.3					285.9	272.8
1910				122.4	174.4	219.4				107.7	141.5	183.2
1911			212.7	263.2	285.5	335.6			31.4	46.6	66.1	65.9
1912		9.1	112.1	101.5	118.1	132.7		54.2	54.8	64.9	97.3	126.6
1913	0.0	0.0	26.2	14.8	31.4		0.9	59.4	58.2	66.3	66.8	
1914	0.0	0.0	4.1	35.9			3.3	15.2	29.6	37.0		
1915	0.0	0.0	5.1				0.0	17.8	50.5			
1916	0.0	13.5					0.0	16.2				
1917	0.0						2.6					
	All Mills											
1908						413.4						
1909					299.4	373.9						
1910				186.9	221.3	236.9						
1911			132.2	159.6	184.2	214.1						
1912		58.8	63.3	66.9	107.7	134.1						
1913	4.9	29.1	35.2	60.1	79.7							
1914	2.1	15.1	32.3	70.2								
1915	0.0	11.1	19.8									
1916	1.2	13.1										
1917	0.9											

Table 5

FAILURES FOR VARIOUS AGES OF RAIL PER 100 TRACK MILES

OPEN HEARTH

Year Rolled	Years Service 0	1	2	3	4	5	Years Service 0	1	2	3	4	5
	Algoma						**Bethlehem**					
1908						482.8						605.7
1909					203.7						466.1	580.9
1910				431.0		13.8				174.0	245.0	330.9
1911			219.7						113.3	195.3	251.7	329.8
1912		124.0						11.9	32.0	52.1	83.2	106.8
1913							1.6	13.4	26.9	52.6	77.3	
1914		19.0	43.2	67.0			0.0	3.8	6.9	16.0		
1915	1.4	7.1	11.8				0.0	17.3	24.5			
1916	4.3	22.7					4.5	17.7				
1917	135.5						12.1					
	Cambria						**Carnegie**					
1908												
1909					244.8	326.6					104.1	127.1
1910				98.5	136.4	201.0				98.9	112.9	101.1
1911			73.7	126.1	227.7	257.2			71.5	108.9	123.1	165.6
1912		17.1	41.8	74.3	108.9	140.9		12.3	30.9	55.3	78.4	98.8
1913	7.1	26.7	49.5	78.3	106.2		2.5	8.9	19.4	33.8	62.9	
1914	1.7	15.8	37.7	61.9			0.8	5.5	11.9	16.6		
1915	1.0	6.3	19.5				0.3	1.8	8.6			
1916	5.4	7.3					0.4	4.9				
1917	14.3						1.5					
	Colorado						**Dominion**					
1908						45.5						1396.9
1909					22.4	34.2					272.6	
1910				19.6	23.4	60.9				850.5		159.9
1911			15.8	31.0	52.6	84.3			246.9		162.3	406.4
1912		18.3	40.9	55.6	91.3	117.6		426.0		33.7	88.2	217.9
1913	1.2	3.9	11.0	26.0	46.6						526.2	
1914	1.0	3.7	7.6	14.1								
1915	0.2	4.6	7.7						46.1			
1916	1.0	5.8						35.7				
1917	0.7											
	Illinois						**Lackawanna**					
1908												143.5
1909					151.9	219.7					100.1	117.8
1910				88.4	136.8	206.2				42.7	90.3	148.9
1911			67.5	94.0	107.7	178.6			29.5	57.1	108.6	162.5
1912		7.4	23.2	39.2	64.6	100.0		4.8	20.1	39.6	67.1	88.6
1913	1.1	10.0	21.9	44.0	62.1		2.3	17.2	31.4	51.9	74.0	
1914	1.0	11.6	30.0	47.3			0.3	1.8	10.0	24.5		
1915	0.1	10.7	21.9				0.2	10.5	23.8			
1916	0.8	11.1					2.4	8.9				
1917	0.7						0.8					
	Maryland						**Pennsylvania**					
1908												72.8
1909											86.3	101.4
1910				69.6	104.8	165.7				81.4	110.9	[illegible]
1911			32.9	49.5	58.5	67.4			34.6	79.6	119.0	[illegible]
1912		11.3	5.8	18.1	8.6	110.8		5.3	15.6	27.5	46.8	60.4
1913	0.9	28.6	74.1	88.4	117.0		1.1	9.6	21.0	54.7	47.3	
1914	1.1	13.3	25.2	31.5			2.5	8.2	21.1	29.4		
1915	8.3	24.5	60.8				0.0	6.3	18.1			
1916	1.6	30.7					0.0	35.6				
1917	49.0						0.0					
	Tennessee						**All Mills**					
1908						86.5						370.5
1909					11.1	83.7					165.6	198.5
1910				32.4	47.8	55.2				81.3	107.1	184.0
1911			14.9	25.1	40.8	61.7			53.0	83.5	111.2	161.9
1912		7.3	32.9	43.9	64.5	83.2		26.3	28.9	46.0	74.2	102.7
1913	1.5	6.7	16.5	24.5	41.6		1.8	11.5	24.8	43.3	68.5	
1914	1.7	7.5	16.6	29.0			1.1	7.9	18.9	30.8		
1915	1.3	6.0	16.0				0.8	8.8	19.0			
1916	2.3	15.6					1.7	11.7				
1917	3.2						5.4					

"All Mills" includes one lot 1912 Rolling from Lorain Steel Co. not shown in this table.

Table 6

AVERAGE WEIGHTS OF RAILS.

Compiled from Tonnages Used in This Report.

Mill	1912	1913	1914	1915	1916	1917
Bessemer						
Algoma	80.0	80.0	94.9			
Cambria	86.1	83.6	85.0			
Carnegie	90.6	96.3	89.9			
Illinois	99.8	85.4	83.6	85.0	81.8	85.6
Lackawanna	88.1	84.1	86.0	85.0	85.0	90.0
Maryland	91.8	89.2	93.8	85.0	85.0	85.0
Average	89.4	86.4	88.9	85.0	83.9	86.9
Open Hearth						
Algoma			96.3	90.4	90.6	95.5
Bethlehem	93.0	95.3	97.2	98.2	100.0	101.1
Cambria	96.1	93.1	101.5	102.5	104.0	125.0
Carnegie	95.2	96.9	97.4	98.2	101.8	106.7
Colorado	86.7	88.0	88.9	89.8	89.0	90.0
Dominion	89.0	83.6		85.0	85.0	
Illinois	90.7	91.3	92.7	93.8	94.0	93.4
Lackawanna	92.0	95.2	94.0	95.6	95.3	95.5
Lorain	100.0					
Maryland	86.1	92.8	92.8	105.6	107.9	100.0
Pennsylvania	92.5	97.1	97.4	105.3	101.9	85.0
Tennessee	83.3	86.0	87.3	88.3	87.5	87.0
Average	91.3	91.9	94.6	95.7	96.1	97.9

Table 7, Sheet 1

Year Rolled	Lbs Per Yd.	Section	Specified Carbon Min	Specified Carbon Max	Total Tons Laid	Equiv Track Miles	Failures to Date: Head	Web	Base	Brkn	Total	Per 100 Trk Mls	Railroad
Total Rail Failures From Date Rolled to October 31st, 1917.													
Bessemer - Algoma Steel Corporation													
1912	80	ASCE	.50	.60	1100	8.76	-	1	1	3	5	57.1	Tem & NO
1913	80	ASCE	.50	.60	1000	7.96	5	2	9	55	71	892.0	Tem & NO
1914	80	ASCE	.50	.60	1000	7.96	3	2	42	25	72	904.5	Tem & NO
	90	ARA-A	.45	.55	3768	26.64	20	-	-	17	37	138.8	G T
	100	ARA-A	.45	.55	1909	12.15	6	1	1	2	10	82.3	G T
	100	ASCE	.45	.55	4010	25.52	28	4	-	10	42	164.6	G T
	100	ASCE	.60	.70	1527	9.71	-	-	-	8	8	82.4	M C
			Totals		12214	81.98	57	7	43	62	169	206.1	
Bessemer - Cambria Steel Company													
1912	85	PS	.62	.75	1909	14.29	5	2	-	10	17	119.0	GB&I
	85	PS	.45	.55	1002	7.50	3	-	4	1	8	106.7	GB&I
	85	PS	.45	.55	1162	8.69	14	1	1	5	21	241.7	PL-NW&C
	85	ASCE	.43	.53	5179	38.77	28	11	2	6	47	121.2	Southern
	90	ASCE	.43	.53	2863	20.24	126	-	-	-	126	622.5	K & M
			Totals		12115	89.49	176	14	7	22	219	244.7	
1913	85	ASCE	.43	.53	7046	52.75	75	18	6	34	133	252.1	Southern
	90	ASCE	.43	.53	1087	7.69	1	-	-	-	1	13.0	K & M
			Totals		8133	60.44	76	18	6	34	134	221.7	
1914	85	ASCE	.43	.53	1544	11.56	8	1	1	-	10	86.5	Southern
Bessemer - Carnegie Steel Company													
1912	85	ASCE	.43	.53	5874	43.98	-	2	-	3	5	11.4	Mon.
	100	ARA-B	.50	.60	4098	26.08	17	-	-	91	108	414.1	B&LE
			Totals		9972	70.06	17	2	-	94	113	161.3	
1913	85	PS	.45	.55	5162	38.65	13	3	-	15	31	80.2	PL-NW&C
	85	PS	.45	.55	2111	15.80	12	1		11	24	151.9	PL-SW
	90	ASCE	.45	.55	1000	7.07	3	2	-	7	12	169.7	Montour
	100	ARA-B	.50	.60	6865	43.69	22	1	-	76	99	226.6	B&LE
	100	PS	.45	.55	10127	64.44	9	2	-	15	26	40.4	PL-NW&C
	100	PS	.45	.55	9272	59.00	9	2	-	6	17	28.8	PL-SW
			Totals		34537	228.65	68	11	-	130	209	91.4	
1914	85	ASCE	.43	.53	4300	32.19	4	1	1	2	8	24.9	Southern
	90	ASCE	.45	.55	4260	30.12	6	-	-	7	13	43.2	Montour
	100	PS	.45	.55	2425	15.43	1	-	-	-	1	6.5	PL-SW
			Totals		10985	77.74	11	1	1	9	22	28.3	
Bessemer - Illinois Steel Company													
1912	75	ASCE	.40	.50	7244	61.46	20	7	79	121	227	369.3	CM&StP
	75	CS	.45	.55	1485	12.60	-	-	-	-	-	0.0	OCRR&N
	**80	ASCE			1000	7.95					6	75.5	CTH&SE
	**80	ASCE			2760	21.88					21	96.0	CTH&SE
	80	ARA-A	.40	.50	7940	63.16	3	-	2	6	12	19.0	G T
	80	ASCE	.43	.53	2143	17.05	5	1	-	9	15	88.0	LE&W
	*85	ASCE			4005	29.99	-	-	1	-	1	3.3	MK&T
	85	ASCE			4200	31.44	17	2	10	101	130	413.5	NYC&StL
	85	ASCE	.43	.53	2685	20.10	7	2	8	-	17	84.6	Southern
	x90	ARA-A	.59	.72	1000	7.07	1	-	-	-	1	14.1	CB&Q
	xx90	ARA-A	.43	.53	4980	35.21	5	4	4	32	45	127.8	CM&StP
	*90	ARA-A	.43	.53	37622	266.01	51	5	18	145	219	82.3	CM&StP
	*100	ARA-A	.45	.55	3629	23.09	5	5	7	19	36	155.9	CM&StP
			Totals		80683	597.01	114	26	130	433	730	122.3	

* Ferro Titanium Alloy Added ** Reported "Total Failures" only x Electric xx Copper

Table 7, Sheet 2

Total Rail Failures From Date Rolled to October 31st, 1917.

Year Rolled	Lbs Per Yd.	Section	Specified Carbon Min	Specified Carbon Max	Total Tons Laid	Equiv Track Miles	Failures to Date Head	Web	Base	Brkn	Total	Per 100 Trk Mls	Railroad
Bessemer - Illinois Steel Company - Cont'd.													
1913	75	ASCE	.40	.50	6145	52.14	16	1	51	23	91	174.5	CM&StP
	75	CS	.45	.55	1823	15.47	-	-	-	-	-	0.0	OWRR&N
	85	KCS	.45	.55	6323	47.34	-	-	-	-	-	0.0	KCS
	85	ARA-A			5250	39.30	8	6	1	7	22	56.0	NYC&StL
	*90	ARA-A	.43	.53	5318	37.60	4	1	2	10	17	45.2	CM&StP
	xx90	ARA-A	.43	.53	8269	58.47	8	5	-	3	16	27.4	CM&StP
	*90	ARA-B	.45	.55	2766	19.56	-	-	-	9	9	46.0	N P
	90	ARA-A	.55	.65	6195	43.80	17	-	4	4	25	57.1	OWRR&N
			Totals		42089	313.68	53	13	58	56	180	57.4	
1914	75.	ASCE	.40	.50	2103	17.84	9	1	4	14	28	156.9	CM&StP
	85	KCS	.45	.55	4038	30.23	3	-	-	2	5	16.5	KCS
	85	ARA-A			5250	39.30	5	1	-	3	9	22.9	NYC&StL
	*90	ARA-B	.45	.55	1194	8.44	-	-	-	-	-	0.0	N P
			Totals		12585	95.81	17	2	4	19	42	43.8	
1915	85	KCS	.45	.55	1510	11.31	-	-	-	-	-	0.0	KCS
	85	ARA-A			2625	19.65	1	1	-	2	4	20.4	NYC&StL
	85	ASCE	.41	.51	2470	18.49	1	1	-	-	2	10.8	Southern
			Totals		6605	49.45	2	2	-	2	6	12.1	
1916	75	ASCE	.40	.50	6605	56.04	3	1	2	9	15	26.8	CM&StP
	75	ASCE			1180	10.01	-	-	-	-	-	0.0	DT&I
	85	ASCE	.59	.76	5450	40.80	-	-	-	2	2	4.9	CGW
	85	ARA-A			2625	19.65	-	-	-	1	1	5.1	NYC&StL
	85	ASCE	.41	.51	6006	44.97	-	-	2	1	3	6.7	Southern
	90	ARA-A	.41	.51	1932	13.66	-	-	-	-	-	0.0	CI&L
			Totals		23798	185.13	3	1	4	13	21	11.3	
1917	85	ASCE	.41	.51	6738	50.44	-	-	-	-	-	0.0	Southern
	90	ARA-A			1082	7.65	-	-	-	-	-	0.0	NYC&StL
			Totals		7820	58.09	-	-	-	-	-	0.0	
Bessemer - Lackawanna Steel Company													
1912	80	ASCE	.40	.50	4750	37.79	66	9	5	16	96	254.1	C V
	80	ASCE	.40	.50	3050	24.10	1	-	6	15	22	91.3	G T
	*85	ASCE	.43	.53	3000	22.46	11	-	2	22	35	155.8	CGW
	85	ASCE	.40	.50	4200	31.44	6	5	2	13	26	82.7	NYC&StL
	*90	ARA-A	.43	.53	1000	7.07	-	-	-	5	5	70.7	CM&StP
	*90	ARA-B	.45	.55	3046	21.54	2	-	-	3	5	23.2	N P
	*90	ASCE	.43	.53	1980	14.00	-	2	2	3	7	50.0	StL-SF
	*90	ARA-A	.43	.53	6277	44.38	11	-	-	12	23	51.8	P M
	*100	ARA-A	.45	.55	2050	13.05	7	3	-	5	15	115.0	C&EI
	100	PS	.45	.55	1647	10.48	23	4	2	6	35	334.0	PL-E
	o100	PS (3)	.45	.55	1003	6.38	8	4	-	-	12	188.1	PL-E
	o100	PS (4)	.45	.55	1001	6.37	13	4	-	-	17	266.9	PL-E
	o100	PS (5)	.45	.55	1025	6.53	25	2	-	1	28	428.8	PL-E
			Totals		34009	245.59	173	33	19	101	326	132.7	
1913	70	ASCE	.45	.55	1400	12.73	-	-	-	1	1	7.9	W&LE
	80	ASCE	.40	.50	3162	25.15	9	1	-	-	10	39.8	G T
	**80	ASCE	.48	.58	1009	8.02	-	-	-	-	-	0.0	LM&SE
	85	ARA-A			5250	39.30	10	7	2	4	23	58.5	NYC&StL
	*90	ARA-B	.45	.55	4160	29.41	3	-	-	-	3	10.2	N P
	100	PS	.45	.55	1008	6.42	-	-	-	1	1	15.6	PL-E
			Totals		15989	121.03	22	8	2	6	38	31.4	
1914	80	ASCE	.48	.48	1215	9.66	-	-	-	-	-	0.0	NM&SE
	85	ARA-A			5250	39.30	15	2	4	5	26	66.2	NYC&StL
	*90	ARA-B	.45	.55	3320	23.47	-	-	-	-	-	0.0	N P
			Totals		9785	72.43	15	2	4	5	26	35.9	
1915	85	ARA-A			2625	19.65	-	-	1	-	1	5.1	NYC&StL
1916	85	ARA-A			2625	19.65	2	-	1	-	3	15.3	NYC&StL
	85	ASCE	.43	.53	1335	10.00	1	-	-	-	1	10.0	Southern
			Totals		3960	29.65	3	-	1	-	4	13.5	
1917	90	ARA-A			1747	12.35	-	-	-	-	-	0.0	NYC&StL

* Ferro Titanium Alloy Added ** 1/10 of 1% M T
x Mayari Bessemer xx Copper o Ferro Titanium Experiment

Table 7, Sheet 3

Total Rail Failures From Date Rolled to October 31st, 1917.

Year Rolled	Lbs Per Yd.	Section	Specified Carbon Min	Specified Carbon Max	Total Tons Laid	Equiv Track Miles	Failures to Date: Head	Web	Base	Brkn	Total	Per 100 Trk Mls	Railroad
Bessemer - Maryland Steel Company													
1912	70	ARA-B	.40	.50	4400	40.00	1	-	-	-	1	2.5	SA&AP
	x80	Dudley	.40	.50	4876	38.79	3	11	13	14	41	105.7	NYC-E
	x80	ASCE	.45	.55	1704	13.55	-	-	-	2	2	14.8	NYNH&H
	85	PS	.43	.53	1001	7.49	-	-	-	-	-	0.0	BC&A
	85	ASCE	.59	.76	1000	7.49	1	1	-	10	12	160.2	CGW
	85	ASCE	.59	.72	3904	29.25	3	-	-	-	3	10.3	Southern
	85	ASCE	.48	.58	3314	24.81	8	-	1	6	15	60.5	Virg'n
	x90	ARA-A	.43	.53	2000	14.14	1	1	-	3	5	35.4	CM&StP
	x90	GN	.43	.53	4660	32.95	7	-	35	116	158	479.5	G N
	x90	ARA-B	.45	.55	1715	12.13	27	-	3	3	33	272.1	N P
	90	ARA-A			4163	29.44	8	-	-	-	8	27.2	S P
	*100	ARA-B	.46	.56	9833	62.57	47	7	-	48	102	163.1	B & O
	100	NYNH&H	.53	--	1670	10.63	1	37	20	11	69	649.1	B & M
	x100	Dudley	.40	.50	2002	12.74	-	-	-	2	2	15.7	NYC-E
	x100	NYNH&H	.45	.55	5200	33.09	3	2	12	9	26	78.6	NYNH&H
	100	PS	.45	.55	20804	132.39	52	73	6	35	166	125.4	PL-E
	100	ASCE			1000	6.56	-	-	-	-	-	0.0	RF&P
			Totals		73246	507.80	162	132	90	259	643	126.6	
1913	75	ASCE	.38	.48	9800	83.18	-	-	-	-	-	0.0	AT&SF
	85	PS	.45	.50	998	7.47	-	-	-	-	-	0.0	BC&A
	85	ASCE	.43	.53	13104	98.11	2	-	-	1	3	3.1	Southern
	90	ARA-A			1101	7.78	3	-	-	-	3	38.6	C & A
	x90	ARA-B	.45	.55	1196	8.46	-	-	-	-	-	0.0	N P
	x90	ARA-A	.43	.53	3098	21.90	4	-	-	-	4	18.3	P M
	100	PS			1158	7.37	12	-	-	-	12	162.8	C V
	100	PS	.45	.55	17551	111.69	59	19	3	13	94	84.2	PL-E
	x100	PS	.45	.55	2627	16.71	12	-	2	6	20	119.7	PL-NW&C
	x100	PS	.45	.55	1030	6.55	14	-	-	31	45	687.0	PL-SW
	100	P&R	.42	.52	1001	6.37	70	-	-	-	70	1098.9	P & R
			Totals		52664	375.56	176	19	5	51	251	66.8	
1914	85	PS	.45	.50	1000	7.49	-	-	-	-	-	0.0	BC&A
	85	ASCE	.43	.53	3403	25.46	4	1	-	1	6	23.6	Southern
	x90	ARA-A	.43	.53	1051	7.43	-	-	-	-	-	0.0	P M
	100	ARA-B	.45	.55	5542	34.00	2	4	-	15	21	61.8	B & O
	100	PS	.45	.55	1500	9.55	-	-	-	-	-	0.0	C V
	x100	PS	.45	.55	1245	7.92	5	1	-	1	7	88.4	PL-SW
			Totals		13541	91.87	11	6	-	17	34	37.0	
1915	85	ASCE	.41	.51	2911	21.79	6	-	1	4	11	50.5	Southern
1916	85	ASCE	.41	.51	13979	104.66	8	4	4	1	17	16.2	Southern
1917	85	ASCE	.41	.51	5046	37.78	-	-	-	1	1	2.6	Southern

* Ferro Titanium Alloy Added x Mayari Bessemer

Table 7, Sheet 4

Total Rail Failures From Date Rolled to October 31st, 1917.													
Year Rol-led	Lbs Per Yd.	Section	Specified Carbon		Total Tons Laid	Equiv Track Miles	Failures to Date						Railroad
			Min	Max			Head	Web	Base	Brkn	Total	Per 100 Trk Mls	
Open Hearth - Algoma Steel Corporation													
1914	90	ASCE	.60	.73	1854	13.11	4	-	-	-	4	30.5	CCC&StL
	90	ARA-A	.65	.76	4190	29.63	14	-	1	4	19	64.1	G T
	100	ASCE	.65	.76	3165	20.14	19	3	1	10	33	163.8	G T
	100	ARA-A	.65	.76	7095	45.15	14	-	-	4	18	39.9	G T
	100	ASCE	.62	.75	1088	6.92	-	-	-	3	3	43.4	M C
			Totals		17392	114.95	51	3	2	21	77	67.0	
1915	80	ASCE	.60	.70	1000	7.96	-	-	-	2	2	25.1	Tem
	80	ASCE	.55	.68	1621	12.89	1	-	-	-	1	7.8	T&OC
	85	CPR	.58	.72	5004	37.46	-	-	-	-	-	0.0	G T
	85	ASCE	.62	.75	1405	10.50	2	-	-	-	2	19.0	KCS
	85	ASCE	.62	.75	1555	11.49	-	-	-	-	-	0.0	KCS
	85	CPR	.59	.72	2695	20.17	-	-	-	-	-	0.0	P M
	90	ARA-A	.65	.76	999	7.06	-	-	-	-	-	0.0	G T
	90	ARA-B	.65	.76	2500	17.68	4	-	-	2	6	33.9	H V
	90	ARA-A	.65	.76	18926	133.82	17	4	2	2	25	18.7	I C
	90	ARA-A	.62	.75	10400	73.53	7	-	-	2	9	12.2	P M
	100	ARA-A	.62	.75	2992	19.04	-	-	-	2	2	10.5	CRI&P
	100	ARA-B	.65	.76	1463	9.31	-	-	-	-	-	0.0	H V
	100	ASCE	.62	.75	5758	36.64	-	-	-	-	-	0.0	M C
			Totals		56299	397.55	31	4	2	10	47	11.8	
1916	85	CPR	.62	.75	2918	21.84	-	-	-	4	4	18.3	P M
	90	ARA-A	.65	.76	2365	16.72	-	-	-	-	-	0.0	G T
	90	ARA-B	.65	.76	1989	14.06	1	2	-	5	8	56.9	H V
	90	ARA-A	.65	.76	11593	81.97	6	5	2	9	22	26.8	I C
	90	ARA-A	.62	.75	4593	32.48	1	-	-	2	3	9.2	P M
	90	ASCE	.60	.73	1149	8.12	-	-	-	1	1	12.3	T&OC
	100	ARA-B	.65	.76	1516	9.65	1	-	-	2	3	31.1	H V
	100	ASCE	.62	.75	2174	13.82	2	-	-	2	4	28.9	M C
			Totals		28297	198.66	11	7	2	25	45	22.7	
1917	90	ARA-A	.65	.76	1495	10.57	-	-	-	-	-	0.0	I C
	100	ARA-B	.62	.76	2049	13.04	24	1	1	6	32	245.4	Virg'n
			Totals		3544	23.61	24	1	1	6	32	135.5	
Open Hearth - Bethlehem Steel Company													
1912	80	ASCE	.62	.75	1981	15.76	-	3	-	12	15	95.2	CNE
	80	ASCE	.59	.72	6800	54.09	1	-	2	4	7	12.9	L&NE
	80	ASCE	.62	.75	3116	24.79	-	-	-	4	4	16.1	NYNH&H
	85	ASCE	.67	.80	1571	11.76	5	7	15	76	103	875.9	B&M
	85	Dudley	.62	.75	5556	41.59	6	5	1	6	18	43.3	SAL
	90	ARA-A	.59	.72	2000	14.14	6	-	2	-	8	56.6	CM&StP
	90	ASCE	.62	.75	14259	100.82	13	1	-	10	24	23.8	D&H
	90	GN	.59	.72	9982	70.58	9	-	1	2	12	17.0	G N
	90	ARA-B	.59	.72	2428	17.17	18	-	3	4	25	145.6	N P
	90	ASCE	.67	.80	5045	35.67	-	2	1	3	6	16.8	P&R
	91	DL&W	.64	.77	3587	25.08	9	1	1	12	23	91.7	DL&W
	100	ARA-B	.70	.80	4233	26.94	47	2	1	45	95	352.6	B&O
	100	NYNH&H	.70	.85	1000	6.36	-	-	2	4	6	94.3	B&M
	100	ARA-A	.67	.80	2735	17.40	2	-	-	-	2	11.5	CNJ
	100	ARA-B	.62	.75	3550	21.32	1	1	-	1	3	14.1	Erie
	*100	ARA-A	.65	.76	15150	96.41	212	7	3	49	271	281.1	L V
	100	Dudley	.62	.75	7386	47.00	5	1	-	-	6	12.8	NYC-E
	100	NYNH&H	.70	.85	3458	21.88	13	8	1	5	27	123.4	NYNH&H
	100	ARA-B	.62	.75	3800	24.18	6	-	-	1	7	28.9	N&W
	100	PS	.62	.75	4601	29.28	1	7	1	11	20	68.3	PRR
	101	DL&W	.70	.85	3897	24.55	8	2	2	53	65	264.7	DL&W
	*110	LV	.65	.76	2140	12.38	30	10	1	1	42	339.3	L V
			Totals		108055	739.15	392	57	37	303	789	106.8	

* Ferro Titanium Alloy Added

Table 7, Sheet 5

Total Rail Failures From Date Rolled to October 31st, 1917.

Year Rolled	Lbs Per Yd.	Section	Specified Carbon Min	Specified Carbon Max	Total Tons Laid	Equiv Track Miles	Failures to Date Head	Web	Base	Brkn	Total	Per 100 Trk Mls	Railroad
Open Hearth - Bethlehem Steel Company. - Cont'd.													
1913	72	NPRyCo	.52	.65	3984	35.21	-	-	-	-	-	0.0	N P
	80	ASCE	.70	.85	1255	9.80	-	1	1	-	2	20.4	L I
	80	ASCE	.62	.75	1099	8.74	-	3	-	3	6	68.6	NYNH&H
	85	ASCE	.67	.80	4600	34.44	3	2	4	4	13	37.8	D&H
	90	ARA-A			981	6.94	2	-	3	4	9	12.9	C&A
	90	ASCE	.67	.80	3006	21.25	-	-	-	2	2	9.8	CNJ
	90	ARA-A	.59	.72	2105	14.88	-	-	-	1	1	6.7	CM&StP
	90	ASCE	.62	.75	7376	52.15	2	-	-	1	3	5.8	D&H
	90	GN	.59	.72	10060	71.13	27	1	31	29	88	123.7	G N
	90	ARA-B	.59	.72	1444	10.21	2	-	-	-	2	19.6	N P
	90	ASCE	.67	.80	5310	37.54	2	1	1	5	9	24.0	P&R
	90	ASCE			4500	31.82	-	-	-	1	1	3.1	W M
	91	DL&W	.64	.77	1902	13.30	3	1	-	18	22	165.4	DL&W
	100	ARA-B	.65	.76	1624	10.35	1	-	-	8	9	87.1	B&O
	100	NYNH&H	.70	.83	3500	22.27	4	1	1	5	11	49.4	D&H
	100	ARA-A	.67	.80	4325	27.52	5	2	-	2	9	33.0	CNJ
	100	ARA-A	.65	.76	1525	9.69	2	-	-	-	2	20.6	CRI&P
	100	ARA-A	.65	.76	4000	25.45	3	1	4	-	8	31.4	Erie
	100	ARA-A	.70	.85	2125	13.51	20	2	-	7	29	214.7	LS&MS
	100	ARA-A	.65	.76	18374	116.95	122	12	3	27	164	140.3	L V
	100	ASCE	.70	.85	2870	18.26	-	-	-	-	-	0.0	L I
	100	NYNH&H	.70	.83	10612	67.53	2	4	6	5	17	25.2	NYNH&H
	100	ARA-B	.62	.75	5300	33.72	13	1	-	14	28	83.0	N&W
	100	PS	.62	.75	3756	23.90	1	4	-	2	7	29.3	PRR-E
	100	P&R	.67	.80	2720	17.31	3	2	-	5	10	57.8	P&R
	100	ARA-B	.65	.67	1072	6.82	18	3	1	33	55	806.6	Virg'n
	*105	Dudley	.62	.75	1033	6.26	2	-	-	2	4	63.9	NYC-E
	105	Dudley	.62	.75	9530	57.76	-	-	-	1	1	1.7	NYC-E
	*110	LV	.65	.76	1201	6.95	11	3	1	7	22	316.5	L V
	110	LV	.65	.76	12905	74.64	125	15	4	7	151	202.3	L V
			Totals		124055	886.26	373	59	57	196	685	77.3	
1914	-80	ASCE	.55	.66	1296	10.31	-	-	-	-	-	0.0	CNE
	80	ASCE	.55	.68	2000	15.91	-	-	-	-	-	0.0	C V
	90	ARA-A	.59	.72	1981	13.65	-	-	1	-	1	7.3	CM&StP
	90	ASCE	.62	.75	12000	84.85	-	-	-	-	-	0.0	D&H
	90	ASCE	.67	.80	5042	35.65	2	1	-	5	8	22.4	P&R
	91	DL&W	.64	.77	2350	16.45	-	-	-	1	1	6.1	DL&W
	100	NYNH&H	.65	.76	1798	11.44	-	-	-	-	-	0.0	B&M
	100	ARA-A	.67	.80	3866	24.60	-	-	-	-	-	0.0	CNJ
	100	ARA-A	.62	.75	5000	31.82	1	-	-	-	1	3.1	Erie
	100	ARA-A	.65	.76	26237	166.97	35	-	1	5	41	24.6	L V
	100	NYNH&H	.65	.76	1066	6.78	1	1	-	-	2	29.5	NYNH&H
	100	ARA-B	.62	.75	4100	26.09	4	-	-	-	4	15.3	N&W
	100	PS	.62	.75	5555	35.34	3	1	-	7	11	31.1	PRR-E
	100	ARA-B	.65	.67	1056	6.72	-	-	-	1	1	14.9	Virg'n
	105	DL&W	.64	.77	1809	10.96	3	-	-	7	10	91.2	DL&W
	105	Dudley	.62	.75	2030	12.30	-	-	-	-	-	0.0	NYC-E
	110	LV	.65	.76	5950	34.42	5	-	-	2	7	20.3	L V
			Totals		85084	544.24	54	3	2	28	87	16.0	
1915	80	ASCE	.59	.72	1700	13.52	-	-	-	-	-	0.0	L&NE
	80	ASCE	.53	.66	1756	15.97	-	-	-	-	-	0.0	NYNH&H
	90	ARA-A	.62	.75	1000	7.07	-	-	-	-	-	0.0	CB&Q
	90	ASCE	.62	.75	2063	14.59	-	-	-	-	-	0.0	D&H
	90	GN	.59	.72	14800	104.65	22	-	1	20	43	41.1	G N
	90	ASCE	.59	.72	4867	34.45	-	1	-	-	1	2.9	L&NE
	90	ASCE			1500	10.61	22	1	-	3	26	245.0	W M
	100	ARA-A	.67	.80	1178	7.50	4	-	-	3	7	93.3	CNJ
	100	ARA-A	.62	.75	4992	31.77	3	-	-	5	8	25.2	Erie
	100	ARA-A	.62	.75	1038	6.61	-	-	-	-	-	0.0	LS&MS
	100	ARA-A	.65	.76	4738	30.15	-	-	-	1	1	3.3	L V
	100	ARA-B	:62	.75	4866	30.96	1	-	-	-	1	3.2	N&W
	100	PS	.62	.75	1450	9.23	-	-	-	-	-	0.0	PRR-E
	100	PS	.60	.75	1450	9.23	2	3	1	14	20	216.7	PRR-E
	100	P&R	.65	.76	3100	19.72	3	-	-	4	7	35.5	P&R
	101	DL&W	.64	.77	4216	26.56	-	-	-	-	-	0.0	DL&W
	105	Dudley	.62	.75	3092	18.74	-	-	-	-	-	0.0	B&A
	105	DL&W	.64	.77	2249	13.63	2	3	-	-	5	36.7	DL&W
	105	Dudley	.62	.75	1240	7.52	-	-	-	-	-	0.0	NYC-E
	107	NYNH&H	.62	.75	12408	73.80	-	-	-	1	1	1.4	NYNH&H
	125	PS	.68	.82	2854	14.53	-	-	-	-	-	0.0	PRR-E
	135	CNJ	.82	.95	1694	7.98	2	-	-	2	4	50.1	CNJ
			Totals		78251	506.79	61	8	2	53	126	24.5	
1916	80	ASCE	.55	.68	2544	20.24	-	-	-	-	-	0.0	C V
	80	ASCE	.70	.85	1370	10.89	-	-	-	-	-	0.0	L I
	90	ASCE	.62	.75	1204	8.51	-	-	-	-	-	0.0	CNJ
	90	ARA-A	.59	.72	1999	14.13	-	-	-	-	-	0.0	CM&StP
	90	ASCE	.62	.75	3807	26.92	-	-	-	-	-	0.0	D&H
	90	GN	.59	.72	4735	35.48	1	-	-	7	8	25.9	G N
	90	ARA-B	.59	.72	2452	17.34	-	1	-	-	1	5.8	N P
	90	ASCE			1000	7.07	-	-	-	1	1	14.1	W M
	90	ASCE			1200	8.49	5	-	-	2	7	82.5	W M
	100	ARA-A	.65	.76	9461	60.22	4	-	-	-	4	6.6	L V
	100	ARA-B	.62	.75	3548	22.58	-	-	-	1	1	4.4	B&O
	100	ARA-A	.67	.80	4716	30.01	6	-	-	-	6	20.0	CNJ
	100	ARA-A	.62	.75	3944	25.10	-	-	-	-	-	0.0	Erie
	100	ARA-A	.62	.75	2634	16.76	3	-	-	-	3	17.9	LS&MS
	100	ASCE	.70	.85	2802	17.83	-	-	-	-	-	0.0	L I
	100	ARA-B	.62	.75	3438	21.88	1	-	-	1	2	9.1	N&W
	100	PS	.60	.75	4290	27.30	4	-	-	-	4	14.6	PRR-E
	100	P&R	.67	.80	2960	18.85	1	-	-	-	1	5.3	P&R
	101	DL&W	.64	.77	1022	6.44	-	-	-	-	-	0.0	DL&W
	105	DL&W	.64	.77	1326	8.04	-	-	-	-	-	0.0	DL&W
	105	Dudley	.62	.75	1051	6.37	-	-	-	-	-	0.0	NYC-E
	125	PS	.68	.82	8128	41.38	-	-	1	12	13	31.4	PRR-E
	135	CNJ	.82	.95	1290	6.08	9	-	-	15	24	394.8	CNJ
	136	LV	.76	.89	2558	11.88	6	1	-	1	8	67.3	L V
			Totals		73459	467.77	40	2	1	40	83	17.7	

* Ferro Titanium Alloy Added

Table 7, Sheet 6

Total Rail Failures From Date Rolled to October 31st, 1917.

Year Rol-led	Lbs Per Yd.	Section	Specified Carbon Min	Specified Carbon Max	Total Tons Laid	Equiv Track Miles	Failures to Date: Head	Web	Base	Brkn	Total	Per 100 Trk Mls	Railroad
					Open Hearth - Bethlehem Steel Company - Cont'd.								
1917	80	ASCE	.55	.68	1090	8.67	-	-	-	-	-	0.0	C V
	80	DL&W	.64	.77	2061	16.38	-	-	-	-	-	0.0	DL&W
	85	ASCE	.59	.72	1800	13.48	-	-	-	-	-	0.0	ACL
	85	ASCE	.62	.75	9250	69.25	-	-	-	-	-	0.0	B&M
	90	ASCE	.62	.75	2018	14.27	-	-	-	-	-	0.0	CNJ
	90	ASCE	.62	.75	5602	39.61	2	-	1	19	22	55.5	D&H
	90	ASCE			2400	16.97	-	-	-	1	1	5.9	W M
	100	ARA-A	.65	.76	2785	17.71	-	-	-	-	-	0.0	L V
	100	ASCE	.70	.85	5611	35.71	-	-	-	-	-	0.0	L I
	101	DL&W	.64	.77	1241	7.82	-	-	-	-	-	0.0	DL&W
	105	Dudley	.62	.75	3150	19.09	-	-	-	-	-	0.0	B&A
	105	DL&W	.64	.77	4065	24.64	-	-	-	-	-	0.0	DL&W
	105	Dudley	.62	.75	5658	34.29	-	-	-	-	-	0.0	NYC-E
	107	NYNH&H	.62	.75	3656	21.74	-	-	-	-	-	0.0	NYNH&H
	135	CNJ	.82	.95	1711	8.06	1	-	-	-	1	12.4	CNJ
	136	LV	.70	.87	12255	57.34	23	2	-	-	25	43.6	L V
			Totals		64353	405.03	26	2	1	20	49	12.1	
					Open Hearth - Cambria Steel Company								
1912	72	NP	.52	.65	1172	10.36	1	-	2	2	5	48.3	N P
	85	ASCE	.62	.75	3300	24.70	-	-	-	8	8	32.4	N&W
	90	ARA-B	.65	.76	1000	7.07	-	-	-	1	1	14.1	CI&L
	90	ARA-A	.59	.72	2000	14.14	2	-	-	-	2	14.1	CM&StP
	90	GN	.59	.72	9840	69.58	8	-	-	5	13	18.7	G N
	90	ARA-B	.65	.76	5108	36.12	2	1	-	2	5	13.8	H V
	90	ARA-A	.59	.72	2595	18.35	-	-	-	1	1	5.5	P M
	90	ARA-A	.65	.76	1566	11.07	6	1	-	-	7	63.2	U P
	100	ARA-A	.70	.80	1065	6.78	1	-	-	2	3	44.2	B&O
	100	ARA-B	.70	.80	23957	152.46	121	16	-	203	340	223.0	B&O
	100	ARA-A	.65	.76	2360	15.02	11	5	2	2	20	133.2	L V
	100	ARA-B	.62	.75	1097	6.98	2	-	-	1	3	43.0	N&W
	100	PS	.62	.75	21739	138.34	105	91	3	173	372	268.9	PRR-E
	100	PS	.62	.75	8064	51.31	13	2	-	8	23	44.8	PR-W-NW&C
	100	PS	.62	.75	1429	9.09	1	1	-	-	2	22.0	PR-W-SW
			Totals		86292	571.35	273	117	7	408	805	140.9	
1913	72	NP	.52	.65	6965	61.58	-	-	-	-	-	0.0	N P
	85	PS	.62	.75	2589	19.39	1	13	-	1	15	77.3	CR&I
	85	ASCE	.62	.75	2559	19.14	-	-	-	3	3	15.7	N&W
	85	PS	.62	.75	2765	20.70	-	63	1	2	66	318.8	PRR-E
	90	ARA-A	.65	.76	8562	60.54	-	8	-	-	8	13.2	B&O
	90	ASCE	.59	.75	1717	12.14	-	-	-	-	-	0.0	CNJ
	90	ARA-B	.65	.76	1000	7.07	-	-	-	-	-	0.0	CI&L
	90	ARA-A	.59	.72	4809	34.00	2	-	-	-	2	5.9	CM&StP
	90	GN	.59	.72	4860	34.36	5	4	1	4	14	40.7	G N
	90	ARA-B	.65	.76	3795	26.82	1	4	-	25	30	111.9	H V
	90	ASCE	.59	.72	1566	11.07	2	-	-	1	3	27.1	K&M
	100	ARA-A	.65	.76	2208	14.05	-	1	-	1	2	14.3	B&O
	100	ARA-B	.65	.76	23008	146.42	76	3	1	180	260	177.6	B&O
	100	ARA-B	.62	.75	2683	17.07	1	1	-	8	10	58.6	N&W
	100	PS	.62	.75	25994	165.42	67	106	2	102	277	167.4	PRR-E
			Totals		95080	649.77	155	203	5	327	690	106.2	
1914	90	ARA-A	.65	.76	1050	7.42	-	1	-	1	2	26.9	B&O
	90	ARA-A	.59	.72	4952	35.01	-	-	-	-	-	0.0	CM&StP
	90	ARA-B	.65	.76	1070	7.57	1	1	-	1	3	39.6	H V
	90	ARA-B	.62	.75	3099	21.91	2	-	-	1	3	13.7	N P
	100	ARA-B	.65	.76	11005	70.02	22	-	1	74	97	138.6	B&O
	100	ARA-B	.65	.76	1536	9.77	-	-	-	1	1	10.2	H V
	100	ARA-B	.62	.75	2304	14.66	1	-	-	2	3	20.5	N&W
	100	PS	.62	.75	3965	25.22	3	10	-	1	14	55.5	PRR-E
	100	PS	.42	.75	4713	29.99	1	16	-	11	28	93.4	PRR-E
	100	PS	.60	.75	4757	30.27	6	2	1	6	15	49.6	PRR-E
	100	PS	.62	.75	8656	55.10	4	7	-	9	20	36.3	PRR-E
	125	PS	.78	.92	9847	50.13	23	4	-	8	35	69.8	PRR-E
			Totals		56954	357.07	63	41	2	115	221	61.9	
1915	85	ASCE	.62	.75	1462	10.94	-	-	-	-	-	0.0	N&W
	90	ARA-A	.62	.75	6350	44.90	-	2	-	-	2	4.5	B&O
	90	ARA-A	.62	.75	1000	7.07	-	-	-	-	-	0.0	CB&Q
	100	ARA-B	.62	.75	13171	83.82	10	-	-	13	23	27.4	B&O
	100	ARA-B	.62	.75	2045	13.01	-	-	-	-	-	0.0	N&W
	100	PS	.60	.75	1003	6.38	-	-	-	1	1	15.7	PRR-E
	100	PS	.60	.75	1996	12.70	-	1	-	-	1	7.9	PRR-E
	100	PS	.60	.75	3294	20.96	1	2	-	3	6	28.6	PRR-E
	100	PS	.60	.75	11501	73.19	2	3	1	5	11	15.0	PRR-E
	125	PS	.68	.88	11729	59.71	14	1	-	6	21	35.2	PRR-E
			Totals		53551	332.68	27	9	1	28	65	19.5	
1916	90	ARA-A	.62	.75	14702	103.96	1	-	-	-	1	1.0	B&O
	90	ARA-A	.59	.72	3009	21.28	-	-	-	-	-	0.0	CM&StP
	90	GN	.59	.72	1464	10.35	-	-	-	-	-	0.0	G N
	90	ARA-B	.62	.75	1371	9.69	-	-	-	-	-	0.0	N P
	100	ARA-B	.62	.75	11023	70.15	5	-	-	-	5	7.1	B&O
	100	ARA-B	.52	.75	3508	22.32	2	-	-	-	2	9.0	N&W
	100	PS	.60	.75	3795	24.14	1	1	-	1	3	12.4	PRR-E
	*125	PS	.62	.75	2005	10.21	1	-	1	-	2	19.6	PRR-E
	125	PS	.68	.88	21501	109.46	13	1	-	1	15	13.7	PRR-E
			Totals		62378	381.56	23	2	1	2	28	7.3	
1917	125	PS	.68	.88	5516	28.09	4	-	-	-	4	14.3	PRR-E

* Ferro Titanium Alloy Added

Table 7, Sheet 7

Total Rail Failures From Date Rolled to October 31st, 1917.													
Year Rol-led	Lbs Per Yd.	Section	Specified Carbon Min	Specified Carbon Max	Total Tons Laid	Equiv Track Miles	Failures to Date Head	Web	Base	Brkn	Total	Per 100 Trk Mls	Railroad
Open Hearth - Carnegie Steel Company													
1912	80	ARA-A	.53	.66	2170	17.26	31	-	-	3	34	197.0	NYO&W
	85	PS	.62	.75	3986	29.84	2	-	-	3	5	16.8	PR-W-NW&C
	90	ARA-B	.65	.85	2187	15.46	93	7	-	27	127	821.5	B&O
	90	ARA-A	.65	.80	8287	58.59	37	1	1	20	59	100.7	B&O
	90	ARA-A	.70	.80	2569	18.16	2	2	-	4	8	44.1	CH&D
	90	ARA-B	.59	.72	16640	117.65	32	7	-	29	68	57.8	Erie
	90	ASCE	.60	.73	1455	10.28	10	8	-	12	30	291.8	W&LE
	100	ARA-A	.70	.80	1218	7.75	9	11	-	16	36	464.5	B&O
	100	ARA-B	.70	.80	7723	49.15	9	3	1	42	55	111.8	B&O
	100	ARA-B	.62	.75	15500	98.63	13	9	3	26	51	51.7	N&W
	100	PS	.62	.75	16628	105.81	15	30	-	28	73	69.0	PR-W-NW&C
	100	PS	.62	.75	9459	60.19	18	9	2	21	50	83.1	PR-W-SW
	100	ARA-B	.62	.75	1585	10.09	-	8	-	3	11	109.0	P&LE
	100	ARA-B	.62	.75	4548	28.94	3	2	-	8	13	44.9	P&LE
			Totals		93955	627.50	274	97	7	242	620	98.8	
1913	80	ARA-A	.63	.76	2370	18.84	7	2	-	2	11	58.4	Erie
	85	ASCE	.62	.75	4275	32.00	2	1	-	5	8	25.0	N&W
	85	D&RG			1115	8.34	-	-	-	1	1	12.0	W P
	90	ARA-A	.65	.76	7824	55.32	14	-	-	4	18	32.5	B&O
	90	ASCE			2298	16.25	1	-	-	3	4	24.6	BR&P
	90	ASCE	.70	.85	4994	35.31	1	1	2	9	13	36.8	P&R
	90	ASCE	.60	.73	4627	32.71	15	2	-	5	22	67.3	W&LE
	100	ARA-B	.65	.76	8168	51.98	13	1	-	36	50	96.2	B&O
	100	ARA-A	.65	.76	8781	55.88	12	2	3	13	30	53.7	B&O
	100	ARA-B	.65	.75	2391	15.22	-	-	-	3	3	19.7	B&LE
	*100	ARA-A	.65	.76	3650	23.23	4	1	-	3	8	34.4	Erie
	100	ARA-A	.65	.76	13135	83.59	30	19	1	22	72	86.1	Erie
	100	ARA-A	.63	.76	6208	39.51	51	6	1	9	67	169.6	L V
	100	ARA-A	.63	.76	7327	46.63	22	4	-	2	28	60.1	L V
	100	ARA-B	.62	.75	13252	84.33	1	1	-	5	7	8.3	N&W
	100	PS	.62	.75	12282	78.12	49	7	2	41	99	126.7	PR-W-NW&C
	100	PS	.62	.75	7658	48.73	5	1	-	12	18	36.9	PR-W-SW
	100	ARA-B	.62	.75	2572	16.37	1	-	-	9	10	61.1	P&LE
	100	ARA-B	.62	.75	3521	22.41	1	6	-	5	12	53.5	P&LE
			Totals		115446	764.77	229	54	9	189	481	62.9	
1914	85	ASCE	.59	.72	5160	38.63	1	-	-	1	2	5.2	CC&O
	90	ASCE			2624	18.55	-	-	-	1	1	5.4	BR&P
	90	ARA-A	.65	.76	1414	10.00	-	-	-	1	1	10.0	CH&D
	90	ASCE	.67	.80	5028	35.55	-	1	-	1	2	5.6	P&R
	100	ARA-B	.65	.76	3159	20.10	-	-	-	16	16	79.6	B&O
	100	ARA-B	.62	.75	2597	16.53	3	1	1	6	11	66.5	B&LE
	100	ARA-A	.62	.75	20528	130.64	6	1	2	2	11	8.4	Erie
	100	ARA-B	.62	.75	1524	9.69	-	1	-	-	1	10.3	LE&W
	100	ARA-B	.62	.75	8400	53.45	-	-	-	-	-	0.0	N&W
	100	PS	.62	.75	3511	22.34	-	4	-	11	15	67.1	PRR-E
	100	PS	.62	.75	9939	63.24	4	-	-	3	7	11.1	PR-W-NW&C
	100	PS	.62	.75	5289	33.65	1	-	-	5	6	17.8	PR-W-SW
	100	ARA-B	.62	.75	1028	6.54	2	-	-	-	2	30.6	P&LE
	100	ARA-B	.62	.75	1749	11.13	-	2	-	1	3	27.0	P&LE
			Totals		71950	470.04	17	10	3	48	78	16.6	
1915	85	ASCE	.62	.75	1061	7.95	-	-	-	-	-	0.0	N&W
	90	ASCE			1095	7.75	-	-	2	1	3	38.8	BR&P
	90	ARA-A	.63	.76	4155	29.38	8	1	1	1	11	37.4	CH&D
	90	ARA-A	.62	.75	8056	56.96	-	-	-	4	4	7.0	CH&D
	90	ASCE	.63	.76	2306	16.30	-	-	-	-	-	0.0	P&R
	90	ASCE	.60	.73	1528	10.80	-	-	-	-	-	0.0	W&LE
	100	ARA-A	.62	.75	5334	33.94	1	-	-	1	2	5.9	B&O
	100	ARA-B	.62	.75	8930	56.83	2	-	-	3	5	8.8	B&O
	100	ARA-B	.62	.75	5769	36.71	7	1	-	8	16	43.6	B&LE
	100	ARA-A	.62	.75	20530	130.65	1	2	-	3	6	4.6	Erie
	100	ARA-B	.62	.75	14025	89.25	-	-	-	-	-	0.0	N&W
	100	PS	.60	.75	1010	6.43	-	3	-	2	5	77.8	PRR-E
	100	PS	.60	.75	1053	6.70	-	1	-	-	1	14.9	PRR-E
	100	PS	.60	.75	24380	155.15	6	-	-	4	10	6.4	PR-W-NW&C
	100	PS	.60	.75	8433	53.66	-	-	-	2	2	3.7	PR-W-SW
	100	ARA-B	.62	.75	3650	23.23	-	-	-	-	-	0.0	P&LE
	100	ARA-B	.62	.75	4789	30.48	-	-	-	-	-	0.0	P&LE
			Totals		116102	752.13	25	8	3	29	65	8.6	
1916	90	ASCE			1556	11.00	-	1	-	1	2	18.2	BR&P
	90	ARA-A	.62	.75	7060	49.92	-	-	-	-	-	0.0	CH&D
	90	ASCE	.63	.76	2000	14.14	-	-	-	-	-	0.0	P&R
	90	ASCE			1000	7.07	-	-	-	-	-	0.0	W M
	90	ASCE	.62	.75	1000	7.07	-	-	-	1	1	14.1	W&LE
	90	ARA-B	.62	.75	4000	28.28	-	-	-	-	-	0.0	W&LE
	100	ARA-A	.62	.75	10130	64.46	3	-	-	-	3	4.7	B&O
	100	ARA-B	.62	.75	17472	111.19	10	-	-	-	10	9.0	B&O
	100	ARA-B	.62	.75	5819	37.03	2	-	-	1	3	8.1	B&LE
	100	ARA-A	.62	.75	15100	96.09	5	2	-	1	8	8.3	Erie
	100	ARA-B	.65	.76	1006	6.40	-	-	-	-	-	0.0	H V
	100	ARA-B	.62	.75	12808	81.50	-	1	-	-	1	1.2	N&W
	100	PS	.60	.75	25108	159.78	-	-	-	1	1	0.6	PR-W-NW&C
	100	PS	.60	.75	9317	59.29	1	-	-	2	3	5.1	PR-W-SW
	100	P&R	.67	.80	2061	13.11	-	-	-	-	-	0.0	P&R
	100	ARA-B	.62	.75	2792	17.77	1	-	-	-	1	5.6	P&LE
	100	ARA-B	.62	.75	2829	18.00	-	-	-	-	-	0.0	P&LE
	130	PS	.68	.87	13172	64.20	9	-	-	2	11	17.1	PRR-E
	130	P&R	.68	.82	1954	9.56	-	-	-	-	-	0.0	P&R
			Totals		136184	855.86	31	4	-	9	44	5.1	
1917	80	ASCE			2200	17.50	-	-	-	-	-	0.0	TStL&W
	100	ARA-B	.62	.75	3537	22.51	1	-	-	-	1	4.4	B&LE
	100	ARA-B	.63	.76	2081	13.24	-	-	-	-	-	0.0	H V
	100	PS	.60	.75	15500	98.64	1	-	-	-	1	1.0	PR-W-NW&C
	100	PS	.60	.75	2180	13.87	-	-	-	-	-	0.0	PR-W-SW
	100	P&R	.67	.80	1065	6.77	-	-	-	-	-	0.0	P&R
	100	ARA-B	.62	.75	3561	22.66	-	-	-	-	-	0.0	P&LE
	130	PS	.68	.87	1935	9.42	-	-	-	-	-	0.0	PRR-E
	130	PS	.68	.87	12500	61.18	2	-	-	-	2	3.3	PR-W-NW&C
			Totals		44557	265.79	4	-	-	-	4	1.5	

* Ferro Titanium Alloy Added

Table 7, Sheet8

Total Rail Failures From Date Rolled to October 31st, 1917.

Year Rolled	Lbs Per Yd.	Section	Specified Carbon Min	Specified Carbon Max	Total Tons Laid	Equiv Track Miles	Failures to Date Head	Web	Base	Brkn	Total	Per 100 Trk Mls	Railroad
Open Hearth - Colorado Fuel & Iron Company													
1912	75	CS	.65	.78	9195	78.02	1	-	-	-	1	1.3	Ore-Elec
	75	CSR	.65	.76	12292	104.29	-	-	-	2	2	1.9	OSL
	75	CS	.55	.68	1671	14.18	-	-	-	-	-	0.0	OWRR&N
	75	CSR			6516	55.28	-	-	-	-	-	0.0	S P
	75	CS	.55	.68	5232	44.39	-	-	-	-	-	0.0	U P
	85	ASCE			6759	50.60	-	1	-	-	1	2.0	C&S
	85	D&RG	.58	.68	10000	74.87	2	-	-	4	6	8.0	D&RG
	85	ASCE			2020	15.12	5	-	-	2	7	46.3	EP&SW-E
	85	ASCE			14966	112.06	11	-	1	4	16	14.3	EP&SW-W
	90	SF	.63	.76	50404	356.39	372	18	3	35	428	120.1	AT&SF
	90	ARA-A	.58	.68	35000	247.45	155	3	-	13	171	69.1	CB&Q
	90	GN	.60	.70	30068	212.60	759	41	54	244	1058	497.6	G N
	90	ARA-A	.59	.72	16206	114.59	52	-	-	16	68	59.3	M P
	90	ARA-B	.58	.68	4337	30.67	97	1	2	1	101	329.3	N P
	90	ARA-A	.63	.76	4611	32.60	68	2	1	2	73	223.9	OSL
	90	ARA-A	.63	.76	11314	80.00	11	-	-	2	13	16.3	OWRR&N
	90	ARA-A			5670	40.09	16	4	-	1	21	52.4	S P
	100	ARA-B	.60	.70	3103	19.75	8	5	-	-	13	65.8	N P
			Totals		229364	1682.94	1535	77	41	326	1979	117.6	
1913	75	CSR	.63	.76	5771	48.97	-	-	-	-	-	0.0	OSL
	75	CS	.55	.68	1512	12.83	-	-	-	-	-	0.0	OWRR&N
	75	CSR			3912	33.19	-	-	-	-	-	0.0	S P
	75	CSR	.55	.68	5346	45.36	2	-	-	-	2	4.4	U P
	85	D&RG	.58	.68	10000	74.87	8	1	1	-	10	13.4	D&RG
	85	ASCE			1945	14.56	3	1	-	1	5	34.3	EP&SW
	90	SF	.63	.76	52415	370.61	139	2	1	23	165	44.5	AT&SF
	90	ARA-A	.58	.68	30000	212.16	38	3	-	1	42	19.8	CB&Q
	90	D&RG	.58	.68	4400	31.11	2	-	-	-	2	6.4	D&RG
	90	ARA-A	.62	.75	9968	70.48	7	-	-	1	8	11.4	M P
	90	ARA-B	.58	.68	14655	103.62	114	2	4	9	129	124.5	N P
	90	ARA-A	.63	.76	19846	140.32	146	4	2	3	155	110.5	OSL
	90	ARA-A	.63	.76	10678	75.50	53	12	-	1	66	87.4	OWRR&N
	90	ARA-A			7203	50.92	14	-	-	-	14	27.5	S P
			Totals		177651	1284.49	526	25	8	39	598	46.6	
1914	75	CSR			2180	18.49	-	-	-	-	-	0.0	S P
	75	CSR	.55	.68	5559	47.17	-	-	-	-	-	0.0	U P
	85	D&RG	.58	.68	2990	22.39	1	-	-	1	2	8.9	U Ry
	90	SF	.63	.76	58555	413.88	23	2	-	2	27	6.5	AT&SF
	90	ARA-A	.62	.75	20000	141.40	22	2	-	-	24	17.0	CB&Q
	90	SF			1414	10.00	-	-	-	-	-	0.0	C M
	90	D&RG	.58	.68	9000	63.64	8	4	-	-	12	18.9	D&RG
	90	ARA-A	.62	.75	3536	25.00	1	-	-	3	4	16.0	M P
	90	ARA-B	.58	.68	1010	7.14	9	-	-	-	9	126.1	N P
	90	ARA-A	.63	.76	8173	57.78	43	-	-	-	43	74.4	OSL
	90	ARA-A	.63	.76	15079	106.62	2	-	-	-	2	1.9	OWRR&N
	90	ARA-A			17727	125.25	15	-	-	8	23	18.4	S P
			Totals		145205	1058.76	124	8	-	14	146	14.1	
1915	85	ASCE			3473	26.00	-	-	-	-	-	0.0	C&S
	90	SF	.63	.76	67812	479.47	19	3	-	2	24	5.0	AT&SF
	90	ARA-A	.62	.75	15000	106.05	2	-	-	-	2	1.9	CB&Q
	90	D&RG	.62	.75	10000	70.71	2	-	-	-	2	2.8	D&RG
	90	ARA-A			3133	22.15	2	-	-	-	2	9.0	EP&SW
	90	ARA-A			10826	76.55	2	-	-	-	2	2.6	EP&SW
	90	ARA-A	.62	.75	8325	58.86	-	-	-	1	1	1.7	M P
	90	ARA-B	.58	.68	3933	27.81	1	-	-	-	1	3.6	N P
	90	ARA-A	.63	.76	8526	60.29	16	-	-	2	18	29.9	OSL
	90	ARA-A	.63	.76	3992	28.23	3	-	-	-	3	10.6	OWRR&N
	90	ARA-A	.63	.76	14237	100.67	22	2	-	2	26	25.8	U P
			Totals		149257	1056.79	69	5	-	7	81	7.7	
1916	75	CSR	.55	.68	4165	35.34	-	-	-	-	-	0.0	StJ&GI
	85	MP	.62	.75	12160	91.04	2	-	-	2	4	4.4	M P
	85	ASCE	.55	.65	7957	59.57	3	-	-	-	3	5.0	T&P
	90	SF	.63	.76	61580	435.41	7	-	-	-	7	1.6	AT&SF
	90	ARA-A	.62	.75	15000	106.05	-	-	-	-	-	0.0	CB&Q
	90	ARA-A			4644	32.84	1	-	-	-	1	3.0	EP&SW
	90	ARA-A	.62	.75	26684	188.74	20	-	-	-	20	10.6	M P
	90	ARA-B	.58	.68	1813	12.82	1	-	1	1	3	23.4	N P
	90	ARA-A	.63	.76	14037	99.25	14	1	-	2	17	17.1	OSL
	90	ARA-A	.63	.76	13940	98.57	-	-	-	-	-	0.0	OWRR&N
	90	ARA-A			4704	33.26	-	-	-	1	1	3.0	S P
	90	ARA-A	.63	.76	15702	111.03	14	1	-	5	20	18.0	U P
			Totals		182386	1305.92	62	2	1	11	76	5.8	
1917	85	MP	.62	.75	13714	102.60	-	-	-	-	-	0.0	M P
	90	SF	.62	.75	41300	292.02	-	-	-	-	-	0.0	AT&SF
	90	ARA-A	.62	.75	15000	106.06	-	-	-	-	-	0.0	CB&Q
	90	ARA-A			1414	10.00	-	-	-	-	-	0.0	C M
	90	D&RG	.62	.75	4458	31.52	-	-	-	-	-	0.0	D&RG
	90	ARA-A	.62	.75	7306	51.70	-	-	-	-	-	0.0	M P
	90	ARA-B	.58	.68	4254	30.08	-	-	1	-	1	3.3	N P
	90	ARA-A	.63	.76	5062	35.79	1	-	-	-	1	2.8	OSL
	90	ARA-A	.63	.76	6532	46.19	2	-	-	-	2	4.3	U P
	100	CS	.63	.76	3452	21.96	-	1	-	-	1	4.6	OWRR&N
	100	CS	.63	.76	3882	24.54	-	-	-	-	-	0.0	U P
			Totals		106574	752.35	3	1	1	-	5	0.7	

Table 7. Sheet 9

Total Rail Failures From Date Rolled to October 31st, 1917.

Year Rolled	Lbs Per Yd.	Section	Specified Carbon Min	Specified Carbon Max	Total Tons Laid	Equiv Track Miles	Failures to Date: Head	Web	Base	Brkn	Total	Per 100 Trk Mls	Railroad
						Open Hearth - Dominion Iron & Steel Company							
1912	80	ASCE			5000	39.77	172	1	22	15	210	528.0	CGR
	80	ASCE	.55	.65	10606	84.37	91	6	10	33	140	165.9	G T
	100	ASCE	.56	.68	15612	99.35	108	4	6	22	137	137.9	G T
			Totals		31218	223.49	371	11	38	70	487	217.9	
1913	80	ASCE			4035	32.10	169	2	14	25	230	716.4	CGR-E
	85	CGR	.55	.70	11680	87.44	353	3	27	16	399	456.3	CGR-E
			Totals		15715	119.54	522	5	41	41	629	526.2	
1915	85	CGR	.55	.70	9850	73.74	29	-	1	4	34	46.1	CGR-E
1916	85	CGR	.55	.70	11980	89.69	11	1	-	20	32	35.7	CGR-E
						Open Hearth - Illinois Steel Company							
1912	72	NP	.52	.65	3110	27.49	-	-	-	-	-	0.0	N P
	75	ASCE	.40	.50	7244	61.46	20	7	79	121	227	369.3	CM&StP
	80	ASCE	.65	.80	1432	11.39	5	-	-	-	5	43.9	B&OCT
	80	ASCE	.52	.65	1501	11.95	1	-	-	1	2	16.7	M&StL
	80	ASCE	.55	.68	7252	57.68	3	1	10	11	25	43.3	NYC-W
	80	ASCE	.55	.68	3919	31.17	6	-	2	32	40	128.3	T&OC
	85	ASCE	.59	.76	6000	44.92	12	-	-	18	30	66.8	CGW
	85	ASCE	.58	.71	1674	12.53	3	-	-	1	4	31.9	IHB
	85	PS	.59	.72	4141	31.05	11	-	-	-	11	35.5	M&StL
	85	ARA-A	.59	.72	19815	148.35	81	1	25	27	134	90.3	MStP&SSM
	85	ASCE	.58	.71	3392	25.39	-	-	-	2	2	7.9	NYC-W
	85	PS	.62	.75	10165	76.10	40	3	2	40	85	111.7	PR-W-SW
	90	SF	.63	.76	1681	11.89	10	-	-	-	10	84.1	AT&SF
	90	ARA-A	.65	.80	2133	15.08	26	4	-	9	39	258.6	B&O
	90	ARA-A			2424	17.14	42	4	1	21	68	396.7	C&A
	90	ARA-A	.62	.75	15000	106.05	92	4	10	19	123	117.9	CB&Q
	90	ARA-A	--	.64	5845	41.33	2	1	-	1	4	9.7	C&EI
	90	ARA-B	.63	.76	6000	42.42	57	3	-	20	80	188.6	CI&L
	90	ARA-A	.59	.72	25122	177.63	6	-	-	15	21	11.8	CM&StP
	90	ARA-B	.45	.49	1032	7.30	-	-	-	6	6	82.2	C&NW
	90	ARA-A	.63	.76	10348	73.16	-	-	-	2	2	2.7	CRI&P
	90	ARA-A	.65	.80	1080	7.64	1	-	-	3	4	52.4	CH&D
	90	ASCE	.60	.73	10500	74.24	26	2	18	11	57	76.8	CCC&StL
	90	ARA-B	.59	.72	31250	220.96	15	6	1	24	46	20.8	Erie
	90	ARA-A	.63	.76	4608	32.58	21	6	6	8	41	125.8	I C
	90	ASCE	.43	.53	1129	7.98	2	1	-	8	11	137.8	LE&W
	90	ARA-A	.59	.72	8975	63.46	6	2	-	2	10	15.8	M P
	90	ARA-B	.62	.75	9078	64.19	190	10	40	39	279	434.6	N P
	90	ARA-A			4077	28.84	2	-	-	-	2	6.9	S P
	90	ASCE	.60	.73	4149	29.34	18	-	-	19	37	126.1	T&OC
	90	ARA-A	.63	.76	3796	26.84	14	-	2	14	30	111.8	U P
	100	ARA-A	.70	.80	7559	48.10	17	1	4	20	42	87.3	B&O
	100	ARA-A	.64	.77	5000	31.82	13	2	1	7	23	72.3	CB&Q
	100	ARA-A	--	.68	3012	19.17	12	2	-	14	28	146.0	C&EI
	100	ARA-A	.62	.75	4648	29.58	2	1	1	2	6	20.3	CM&StP
	100	C&NW	.62	.75	22895	145.70	76	-	3	46	125	86.0	C&NW
	100	ARA-A	.63	.76	13494	85.87	68	3	1	12	84	97.8	CRI&P
	100	ASCE	.62	.75	3673	23.37	16	33	5	11	65	278.2	M C
	100	ASCE	.62	.75	10995	69.96	24	16	16	50	106	151.5	NYC-W
	100	PS	.62	.75	10780	68.60	88	5	9	40	142	207.0	PR-W-NW&C
	100	PS	.62	.75	3325	21.16	25	1	1	32	59	278.8	PR-W-SW
	100	PS	.62	.75	5954	37.88	43	1	2	5	51	134.6	PRR-W
			Totals		309207	2168.74	1096	120	259	713	2168	100.0	
1913	75	ASCE	.53	.66	6382	54.15	4	-	-	3	7	12.9	AT&SF
	75	CS-R			14391	122.10	2	-	-	-	2	1.8	S P
	80	ASCE	.53	.66	1638	13.03	2	5	-	2	9	69.1	B&OCT
	80	ASCE	.55	.68	4850	38.58	5	-	-	6	11	28.5	LE&W
	80	ASCE	.55	.68	2850	22.67	3	-	3	3	9	39.7	NYC-W
	80	ASCE	.55	.68	2577	20.50	6	4	3	17	30	146.3	T&OC
	85	ASCE	.59	.76	6000	44.92	5	-	6	10	21	46.8	CGW
	85	PS	.62	.75	1202	9.00	5	-	-	8	13	144.4	GR&I
	85	ASCE	.58	.71	1350	10.11	5	-	-	4	9	89.0	IHB
	85	PS	.59	.72	8425	63.08	-	-	-	-	-	0.0	M&StL
	85	ARA-A	.59	.72	3820	28.60	5	-	-	7	12	42.0	MStP&SSM
	85	ARA-A	.59	.72	10306	77.18	-	-	-	12	12	15.6	MStP&SSM
	85	ARA-A	.59	.72	5092	38.12	14	-	-	-	14	36.7	MStP&SSM
	85	ARA-A	.59	.72	4395	32.94	11	5	9	11	36	109.3	MStP&SSM
	85	ASCE	.58	.71	8141	60.94	1	2	-	12	15	24.6	NYC-W
	90	SF	.65	.76	13480	95.31	40	1	1	6	48	50.4	AT&SF
	90	ARA-A			6000	42.42	-	-	-	4	4	9.4	C&A
	90	ARA-A			11426	80.78	22	8	1	9	40	49.5	C&A
	90	ARA-A	.62	.75	25000	176.75	84	4	19	40	147	83.2	CB&Q
	90	ARA-A	.59	.72	7755	54.83	24	1	1	1	27	49.2	C&EI
	90	ARA-B	.63	.76	4000	28.28	17	-	-	2	19	67.2	CI&L
	90	ARA-A	.59	.72	13127	92.82	28	-	3	30	61	65.7	CM&StP
	90	ARA-B	.45	.49	990	7.00	-	-	-	2	2	28.4	C&NW
	90	ARA-A	.63	.76	13079	92.48	5	-	-	1	6	6.5	CRI&P
	90	ASCE	.60	.73	12600	89.09	44	8	4	17	73	81.9	CCC&StL
	90	GN	.59	.72	14590	103.18	15	1	27	64	107	103.7	G N
	90	ARA-A	.63	.76	10964	77.52	138	6	17	31	192	247.7	I C
	90	ARA-B	.62	.75	23475	165.98	96	4	36	68	204	122.9	N P
	90	ARA-A	.59	.72	12750	90.16	10	-	-	3	13	14.4	P M
	90	ARA-A			51945	367.30	50	57	3	98	208	56.6	S P
	90	ASCE	.60	.73	5505	38.91	1	2	-	4	7	18.0	T&OC
	90	ARA-A	.63	.76	8784	62.11	85	1	1	11	98	157.8	U P
	100	ARA-A	.63	.76	9166	58.33	14	1	4	12	31	53.1	B&O
	100	ARA-A	.64	.77	5000	31.82	9	2	4	2	17	53.4	CB&Q
	100	ARA-A	.62	.75	10072	64.10	2	2	4	11	19	29.6	CM&StP
	100	ARA-A	.62	.75	1502	9.56	2	-	1	-	3	31.4	CM&StP
	100	ARA-A	.62	.75	1939	12.34	4	1	-	2	7	56.7	C&EI
	100	C&NW	.62	.75	44124	280.80	39	7	2	36	84	30.0	C&NW
	100	ARA-A	.63	.76	13335	84.86	31	-	1	2	34	40.1	CRI&P
	100	ARA-A	.63	.76	4500	28.64	3	1	1	2	7	24.4	Erie
	100	ASCE	.62	.75	15567	99.06	36	51	4	55	146	147.4	M.C
	100	ASCE	.62	.75	2000	12.72	1	-	-	-	1	7.9	NYC-W
	100	ASCE	.62	.75	15288	97.28	16	2	14	38	70	72.0	NYC-W
	100	PS	.62	.75	9487	60.37	78	-	-	2	80	132.5	PRR-E
	100	PS	.62	.75	13246	84.28	29	2	1	6	38	45.1	PR-W-NW&C
	100	PS	.62	.35	2322	14.78	8	-	1	9	18	121.8	PR-W-SW
			Totals		464433	3239.94	999	178	171	663	2011	62.1	

Table 7, Sheet 10

Total Rail Failures From Date Rolled to October 31st, 1917.

Open Hearth - Illinois Steel Company - Cont'd.

Year Rolled	Lbs Per Yd.	Section	Specified Carbon Min	Specified Carbon Max	Total Tons Laid	Equiv Track Miles	Failures to Date: Head	Web	Base	Brkn	Total	Per 100 Trk Mls	Railroad
1914	75	CSR	.55	.68	3397	28.82	-	-	-	-	-	0.0	U P
	80	ASCE	.55	.68	1573	12.51	-	-	1	7	8	64.0	M C
	80	ASCE	.55	.68	2052	16.32	1	-	12	5	18	110.3	NYC-W
	80	ASCE	.55	.68	1578	12.55	3	-	-	15	18	143.4	T&OC
	85	ASCE	.59	.76	6000	44.92	3	4	24	24	55	122.4	CGW
	85	PS	.59	.72	1578	11.81	3	-	1	-	4	33.8	M&StL
	85	ARA-A	.59	.72	5590	41.85	1	-	3	33	37	88.4	MStP&SSM
	85	ARA-A	.59	.72	3940	29.50	1	-	-	5	6	20.3	MStP&SSM
	85	ARA-A	.59	.72	3400	25.46	-	-	-	-	0	0.0	MStP&SSM
	85	ASCE	.58	.71	1770	13.25	-	-	-	-	-	0.0	NYC-W
	90	ARA-A			6972	49.30	17	-	2	2	21	42.6	C&A
	90	ARA-A	.62	.75	17500	123.73	-	-	-	-	-	0.0	CB&Q
	90	ARA-A	.59	.72	9667	68.35	1	-	3	11	15	22.0	CM&StP
	90	ARA-B	.45	.49	1004	7.10	1	1	-	23	25	352.0	C&NW
	90	ASCE	.60	.73	7875	55.68	11	3	4	5	23	41.3	CCC&StL
	90	GN	.59	.72	9010	63.72	95	2	2	78	177	277.8	G N
	90	ARA-A	.65	.76	27825	196.74	56	1	17	16	90	45.7	I C
	90	ARA-B	.62	.75	996	7.04	1	-	2	3	6	85.2	N P
	90	ARA-B	.62	.75	13906	98.32	35	2	6	31	74	75.3	N P
	90	ARA-A	.59	.72	2102	14.85	-	-	-	1	1	6.7	P M
	90	ASCE	.60	.73	1050	7.42	-	-	-	1	1	13.5	T&OC
	100	ARA-A	.63	.76	4734	30.13	1	-	1	-	2	6.6	B&O
	100	ARA-A	.64	.77	7500	47.72	-	-	-	-	-	0.0	CB&Q
	100	ARA-B	.63	.76	3150	20.05	-	-	-	-	-	0.0	CI&L
	100	ARA-A	.62	.75	3428	21.81	1	-	1	10	12	55.0	CM&StP
	100	C&NW	.62	.75	18416	117.20	6	-	-	2	8	6.8	C&NW
	100	ARA-A	.63	.76	10067	64.19	9	-	2	3	14	21.8	CRI&P
	100	ARA-A	.62	.75	5972	38.00	-	2	-	4	6	15.8	Erie
	100	ASCE	.62	.75	3680	23.41	4	-	2	2	8	34.2	M C
	100	ASCE	.62	.75	10340	65.80	11	3	11	9	34	51.7	NYCW
	100	PS	.62	.75	5808	36.96	19	2	-	-	21	56.8	PRR-E
	100	PS	.62	.75	13126	83.53	6	-	-	3	9	10.8	PR-W-NW&C
	100	PS	.62	.75	4802	30.56	12	-	-	9	21	68.7	PR-W-SW
			Totals		219828	1508.60	298	20	94	302	714	47.3	
1915	80	ASCE	.55	.66	1962	15.61	1	-	-	2	3	19.2	B&OCT
	80	ASCE	.55	.68	2652	20.94	3	-	-	-	3	14.3	C N
	80	ASCE	.55	.68	1622	12.90	-	-	-	-	-	0.0	LE&W
	80	ASCE	.55	.68	2945	23.41	-	-	2	21	23	98.2	M C
	80	ASCE	.56	.68	2500	19.88	2	-	5	7	14	70.4	NYC-W
	85	ASCE	.59	.76	6000	44.92	5	2	2	21	30	66.8	CGW
	85	ASCE	.58	.71	1299	9.73	1	-	-	1	2	20.6	IHB
	85	PS	.59	.72	4346	32.54	2	-	-	-	2	6.1	M&StL
	85	ARA-A	.59	.72	948	7.10	-	-	-	-	-	0.0	MStP&SSM
	85	ARA-A	.59	.72	1736	13.00	-	-	-	2	2	15.4	MStP&SSM
	85	ARA-A	.59	.72	1893	14.18	-	-	-	4	4	28.2	MStP&SSM
	85	ASCE	.58	.71	1500	11.23	-	-	-	2	2	17.8	NYC-W
	90	SP	.63	.76	12730	90.01	2	-	-	2	4	4.4	AT&SF
	90	ARA-A	.62	.75	2102	14.86	-	-	1	5	6	40.4	B&O
	90	ARA-A			11032	78.00	9	-	-	-	9	11.5	C&A
	90	ARA-A	.62	.75	6000	42.42	2	-	-	-	2	4.7	CB&Q
	90	ARA-A	.59	.72	10004	70.73	-	-	-	-	-	0.0	C&EI
	90	ARA-B	.63	.76	4400	31.11	-	-	-	2	2	6.4	CI&L
	90	ARA-A	.59	.72	14380	101.68	7	1	7	80	95	93.5	CM&StP
	90	ARA-B	.45	.49	7200	50.90	-	-	-	5	5	9.8	C&NW
	90	ASCE	.60	.73	17000	120.20	10	1	-	1	12	10.0	CCC&StL
	90	ARA-A	.63	.76	1379	9.75	-	-	-	-	-	0.0	G T
	90	GN	.59	.72	3204	22.66	4	-	-	5	9	39.7	G N
	90	ARA-A	.63	.76	7567	53.50	16	1	7	4	28	52.3	I C
	90	ARA-B	.62	.75	4478	31.66	21	-	1	1	23	72.6	N P
	90	ARA-B	.57	.70	5158	36.47	12	-	7	2	22	60.3	N P
	90	ARA-A	.63	.76	8962	63.37	7	-	-	1	8	12.6	U P
	100	ARA-A	.62	.75	5309	33.79	1	-	2	8	11	32.6	B&O
	100	ARA-A	.64	.77	9000	57.27	1	-	-	-	1	1.7	CB&Q
	100	C&NW	.62	.75	20000	127.30	2	1	-	10	13	10.2	C&NW
	100	ARA-A	.62	.75	26307	167.41	10	-	2	6	18	10.8	CRI&P
	100	ARA-A	.62	.75	5975	38.02	-	-	1	1	2	5.2	Erie
	100	ARA-A	.63	.76	4608	29.33	-	-	-	1	1	3.4	G T
	100	ASCE	.62	.75	8613	54.81	2	-	-	2	4	7.3	M C
	100	ASCE	.62	.75	21000	133.64	3	2	6	13	24	18.0	NYC-W
	100	PS	.62	.75	5197	33.07	5	-	-	-	5	15.1	PRR-E
	100	PS	.60	.75	1059	6.74	-	-	-	-	-	0.0	PR-W-NW&C
	100	PS	.60	.75	1092	6.94	15	-	-	-	15	216.1	PR-W-NW&C
	100	PS	.60	.75	10388	66.10	2	-	-	11	13	19.7	PR-W-NW&C
	100	PS	.60	.75	22800	145.09	2	-	-	7	9	6.2	PR-W-SW
	105	Dudley	1.00	1.25	981	5.95	-	-	-	-	-	0.0	NYC-E
			Totals		287306	1948.22	148	8	43	227	426	21.9	

Table 7, Sheet 11

Total Rail Failures From Date Rolled to October 31st, 1917.

Year Rol-led	Lbs Per Yd.	Section	Specified Carbon Min	Specified Carbon Max	Total Tons Laid	Equiv Track Miles	Failures to Date: Head	Web	Base	Brkn	Total	Per 100 Trk Mls	Railroad
Open Hearth - Illinois Steel Company - Cont'd.													
1916	80	ASCE	.55	.68	2061	16.39	-	-	-	-	-	0.0	B&OCT
	80	ASCE	.55	.68	1923	15.30	-	-	-	-	-	0.0	C N
	80	ASCE	.55	.68	2635	20.96	-	-	-	-	-	0.0	LE&W
	80	ASCE	.56	.68	1300	10.34	-	-	1	1	2	19.3	NYC-W
	85	ASCE	.59	.76	10000	74.87	3	1	8	22	34	45.4	C&W
	85	ARA-A	.59	.72	4504	33.69	-	-	-	2	2	5.9	MStP&SSM
	85	ARA-A	.59	.72	2725	20.41	1	-	-	1	2	9.8	MStP&SSM
	85	ASCE			2405	18.01	-	-	1	-	1	5.5	M&O
	90	SF	.62	.75	11180	79.05	3	-	-	-	3	3.8	AT&SF
	90	ARA-A	,62	.75	1354	9.57	-	-	-	-	-	0.0	B&O
	90	ARA-A			12729	90.00	1	-	-	-	1	1.1	C&A
	90	ARA-A	.62	.75	10000	70.71	3	-	1	5	9	12.7	CB&Q
	90	ARA-A	.59	.72	10000	70.71	1	-	-	-	1	1.4	C&EI
	90	ARA-B	.45	.76	6225	44.01	6	-	-	3	9	20.5	CI&L
	90	ARA-A	.59	.72	8727	61.71	-	-	-	-	-	0.0	CM&StP
	90	ARA-B	.45	.49	9122	64.40	-	-	-	4	4	6.2	C&NW
	90	ARA-A	.62	.75	14040	99.27	-	-	-	-	-	0.0	CRI&P
	90	ARA-A	.62	.75	6456	45.51	1	-	1	-	2	4.4	CH&D
	90	ASCE	.60	.75	20000	141.41	6	-	1	4	11	7.8	CCC&StL
	90	ARA-A	.65	.76	3816	26.98	-	-	-	-	-	0.0	G T
	90	GN	.59	.72	14827	104.85	5	-	-	12	17	16.2	G N
	90	ARA-A	.65	.76	10609	74.98	25	9	3	3	40	53.4	I C
	90	AREA	.59	.72	1785	12.63	-	-	-	-	-	0.0	M&StL
	90	ARA-B	.62	.75	7943	56.16	5	-	1	2	8	14.2	N P
	90	ARA-A	.65	.76	17024	120.38	11	3	-	3	17	14.1	U P
	100	ARA-A	.62	.75	15265	97.14	-	3	12	11	26	26.8	B&O
	100	ARA-A	.64	.77	5000	31.82	-	-	4	-	4	12.0	CB&Q
	100	ARA-A	.59	.72	4727	30.08	1	1	-	24	26	86.4	CM&StP
	100	C&NW	.62	.75	13051	82.90	-	-	-	1	1	1.2	C&NW
	100	ARA-A	.62	.75	31442	200.09	2	1	3	8	14	7.0	CRI&P
	100	ARA-A	.62	.75	4100	26.09	-	-	-	-	-	0.0	Erie
	100	ARA-A	.65	.76	5502	36.01	-	-	-	-	-	0.0	G T
	100	ASCE	.62	.75	6283	39.98	-	-	-	1	1	2.5	M C
	100	ASCE	.62	.75	1600	10.18	2	1	-	-	3	29.5	NYC-W
	100	PS	.60	.75	6180	39.35	-	-	-	1	1	2.5	PRR-E
	100	PS	.60	.75	8321	52.95	-	-	1	8	9	17.0	PR-W-NW&C
	100	PS	.60	.75	30550	194.26	1	-	3	7	11	5.7	PR-W-SW
	105	Dudley	.62	.75	8914	54.02	-	-	-	-	-	0.0	M C
	105	Dudley	.00	1.35	1263	7.66	-	-	-	-	-	0.0	NYC-E
	105	Dudley	.62	.75	16407	99.44	3	1	-	1	5	5.0	NYC-W
		Totals			351985	2385.22	78	20	40	126	264	11.1	
1917	80	ASCE	.55	.66	2092	16.64	-	-	-	-	-	0.0	B&OCT
	80	ASCE			1800	14.32	-	-	-	-	-	0.0	TStL&W
	85	AREA	.59	.72	5705	42.75	-	-	-	-	-	0.0	M&StL
	85	ASCE			1969	14.74	-	-	-	-	-	0.0	M&O
	90	SF	.62	.75	11144	78.80	-	-	-	-	-	0.0	AT&SF
	90	ARA-A			6782	47.95	-	-	-	-	-	0.0	C&A
	90	ARA-A	.62	.75	13273	93.86	-	-	-	-	-	0.0	CB&Q
	90	ARA-A	.59	.72	9640	68.16	-	-	-	-	-	0.0	C&EI
	90	ARA-B	.65	.76	4124	29.16	-	-	-	-	-	0.0	CI&L
	90	ARA-B	.62	.75	17621	124.58	-	-	-	-	-	0.0	N P
	90	ARA-A	.62	.75	1584	11.20	-	-	-	-	-	0.0	CRI&P
	90	ASCE	.60	.75	20000	141.41	-	-	-	1	1	0.7	CCC&StL
	90	GN	.59	.72	9090	64.27	3	-	-	-	3	4.7	G N
	90	ARA-A	.65	.76	11836	83.69	3	-	1	-	4	4.8	I C
	90	ARA-A	.65	.76	2259	15.97	-	-	-	-	-	0.0	OWR&N
	90	ASCE	.60	.75	2000	14.14	-	-	-	-	-	0.0	B&OC
	90	ARA-A	.65	.76	12047	85.18	-	-	-	-	-	0.0	U P
	100	ARA-A	.64	.77	5082	32.34	-	-	-	-	-	0.0	CB&Q
	100	ARA-A	.62	.75	2508	15.96	-	-	-	-	-	0.0	CM&StP
	100	ARA-A	.62	.75	6081	38.70	-	-	-	-	-	0.0	CRI&P
	100	PS	.60	.75	1919	12.21	-	-	-	-	-	0.0	GR&I
	100	ASCE	.62	.75	4418	28.12	-	-	-	-	-	0.0	M C
	100	PS	.60	.75	1446	9.30	-	-	-	-	-	0.0	PRR-E
	100	PS	.60	.75	3400	21.64	-	-	-	-	-	0.0	PR-W-NW&C
	100	PS	.60	.75	11738	74.69	-	-	-	2	2	2.7	PR-W-SW
	105	Dudley	.62	.75	14273	86.50	-	-	-	-	-	0.0	M C
	105	Dudley	.62	.75	19000	115.15	-	-	-	-	-	0.0	NYC-W
		Totals			208551	1361.33	6	-	1	3	10	0.7	
Open Hearth - Lackawanna Steel Company													
1912	72	NP	.52	.65	3404	30.09	-	-	-	-	-	0.0	N P
	80	Dudley	.55	.68	20000	159.10	60	5	5	37	107	67.3	NYC-E
	85	ASCE	.65	.78	4400	32.94	1	1	-	7	9	27.3	B&M
	85	Dudley	.59	.72	6006	44.96	1	-	-	-	1	2.2	SAL
	90	ARA-B	.59	.72	9886	69.90	10	14	2	9	35	50.1	Erie
	90	GN	.62	.75	38180	269.62	32	-	11	15	58	21.5	G N
	90	ASCE	.62	.75	2504	17.71	20	3	-	30	53	299.2	P&R
	90	Dudley	.60	.75	2500	17.68	-	-	-	1	1	5.7	Rutland
	100	Dudley	.62	.75	12965	82.51	27	2	2	14	45	54.5	B&A
	100	ASCE			2360	15.02	5	1	-	1	7	46.6	NH&P
	100	ARA-A	.65	.76	5785	36.81	326	10	2	39	377	1024.2	L V
	100	Dudley	.60	.72	35545	226.20	10	-	4	23	37	16.4	NYC-E
	100	PS	.62	.75	3468	22.07	38	17	-	95	150	679.7	PRR-E
	101	DL&W	.70	.85	14820	89.66	42	8	3	54	107	119.3	DL&W
		Totals			151183	1114.37	572	61	29	325	987	88.6	

Table 7, Sheet 12

Year Rolled	Lbs Per Yd.	Section	Specified Carbon Min	Specified Carbon Max	Total Tons Laid	Equiv Track Miles	Failures to Date: Head	Web	Base	Brkn	Total	Per 100 Trk Mls	Railroad
Total Rail Failures From Date Rolled to October 31st, 1917.													
Open Hearth - Lackawanna Steel Company - Cont'd.													
1913	80	Dudley	.55	.68	22559	179.45	6	2	5	45	58	32.3	NYC-E
	80	ASCE	.55	.68	4400	35.00	-	-	5	1	6	17.1	NYC-W
	80	ARA-A	.53	.66	2150	17.10	-	-	-	-	-	0.0	NYS&W
	85	ASCE	.65	.78	8602	64.40	4	-	7	11	22	34.2	B&M
	85	Dudley	.62	.75	4201	31.45	4	-	-	1	5	15.9	SAL
	90	ASCE			2210	15.63	12	-	1	11	24	153.6	BR&P
	90	ARA-A			1055	7.46	-	-	-	-	-	0.0	C&A
	90	ARA-A	.59	.72	5000	35.35	1	1	5	9	16	45.3	CB&Q
	90	ARA-A	.59	.72	4931	34.87	7	1	-	-	8	22.9	CM&StP
	90	GN	.62	.75	15180	107.34	56	2	10	37	105	97.8	G N
	90	ARA-A	.59	.72	10433	73.78	4	-	-	2	6	8.1	P M
	90	ASCE	.62	.75	2995	21.18	59	3	2	194	258	1123.6	P&R
	90	Dudley	.60	.73	2500	17.68	-	-	-	1	1	5.7	Rutland
	91	DL&W	.67	.80	1491	10.43	1	-	-	7	8	76.7	DL&W
	100	NYNH&H	.62	.75	9785	62.27	5	-	1	-	6	9.6	B&M
	100	ASCE			1876	11.94	4	-	-	-	4	33.5	BR&P
	100	ARA-A	.63	.76	1454	9.25	-	-	-	-	-	0.0	CRI&P
	100	ARA-A	.63	.76	8000	50.90	23	-	-	30	53	104.1	Erie
	100	ARA-A	.63	.76	8323	52.97	247	5	3	33	288	543.7	L V
	100	ASCE	.62	.75	5550	34.04	5	-	4	17	26	76.4	M C
	100	PS	.62	.75	14347	91.30	15	6	1	8	30	32.9	PRR-E
	101	DL&W	.67	.80	11780	74.22	31	1	-	67	99	133.4	DL&W
	105	Dudley	.62	.75	8585	52.05	7	1	1	4	13	25.0	B&A
	105	Dudley	.62	.75	62166	376.76	25	3	17	24	69	18.3	NYC-E
			Totals		219575	1466.80	496	25	62	502	1085	74.0	
1914	75	B&M	.55	.66	1090	9.25	-	-	-	-	-	0.0	B&M
	80	Dudley	.55	.68	22528	177.61	1	-	-	9	10	5.6	NYC-E
	80	ARA-A	.53	.66	1650	13.12	-	-	-	-	-	0.0	NYS&W
	85	ASCE			1003	7.51	1	-	-	-	1	13.3	A A
	85	Dudley	.62	.75	3945	29.51	1	-	-	-	1	3.4	SAL
	90	ARA-A	.59	.72	3000	21.21	3	-	-	-	3	14.1	CB&Q
	90	ARA-A	.59	.72	4965	35.11	-	-	-	-	-	0.0	CM&StP
	90	ARA-A	.62	.75	2040	14.42	9	5	-	3	17	117.9	Erie
	90	ARA-A	.59	.72	2073	14.65	-	-	-	-	-	0.0	P M
	90	ASCE	.67	.80	3009	21.27	4	-	-	56	60	282.1	P&R
	91	DL&W	.64	.77	3660	25.59	2	1	-	-	3	11.7	DL&W
	100	ASCE			3515	22.37	1	1	-	-	2	8.9	BR&P
	100	ARA-A	.62	.75	2829	18.01	1	1	-	-	2	11.1	Erie
	100	ARA-A	.63	.76	4106	26.13	6	1	-	2	9	34.4	L V
	100	PS	.60	.75	2855	18.16	-	-	-	-	-	0.0	PRR-E
	100	PS	.62	.75	3056	19.45	1	-	1	2	4	20.6	PRR-E
	101	DL&W	.64	.77	4451	27.92	21	1	-	45	67	240.0	DL&W
	105	Dudley	.62	.75	5070	30.73	1	1	1	-	3	9.8	B&A
	105	DL&W			2056	12.46	1	-	-	-	1	8.0	DL&W
	105	Dudley	.62	.75	1277	7.74	-	-	-	-	-	0.0	NYC-E
	105	Dudley	.62	.75	34980	212.00	2	-	-	2	4	1.9	NYC-E
			Totals		112956	764.22	55	11	2	119	187	24.5	
1915	80	ASCE	.55	.68	1514	12.04	-	-	-	-	-	0.0	C V
	80	Dudley	.55	.68	6592	52.43	1	-	1	4	6	11.4	NYC-E
	85	ASCE	.62	.75	7725	57.83	-	-	-	2	2	3.5	B&M
	90	ARA-A	.62	.75	3000	21.21	-	-	-	-	-	0.0	CB&Q
	90	ARA-A	.63	.76	1092	7.72	-	-	-	-	-	0.0	G T
	90	GN	.59	.72	12477	88.22	5	-	-	4	9	10.2	G N
	90	ARA-B	.59	.72	7624	53.91	4	-	-	2	6	11.1	N P
	90	ASCE	.67	.80	1500	10.60	1	1	-	4	6	56.6	P&R
	90	ARA-A	.63	.76	1105	7.81	-	-	-	-	-	0.0	U P
	100	NYNH&H	.62	.75	3910	24.88	1	-	-	2	3	12.1	B&M
	100	ASCE			1821	11.59	2	-	-	1	3	25.9	BR&P
	100	ARA-A	.62	.75	9524	60.61	-	-	-	1	1	1.7	Erie
	100	ASCE	.62	.75	3500	22.27	3	-	1	-	4	18.0	NYC-W
	100	ARA-B	.62	.75	1011	6.43	11	-	-	3	14	217.7	B&O
	100	PS	.60	.75	4189	26.66	2	-	-	1	3	11.3	PRR-E
	100	ARA-B	.63	.67	1000	6.36	1	-	-	-	1	15.7	Virg'n
	105	Dudley	.62	.75	5274	31.96	1	1	-	-	2	6.3	B&A
	105	DL&W	.64	.77	4579	27.75	9	1	1	-	11	39.7	DL&W
	105	Dudley	.62	.75	2089	12.66	-	-	-	-	-	0.0	NYC-E
	105	Dudley	.62	.75	28072	170.13	1	-	-	1	2	1.2	NYC-E
	107	NYNH&H	.62	.75	2068	12.42	-	-	-	1	1	8.1	NYNH&H
	125	PS	.68	.82	2715	13.81	91	2	1	8	102	738.6	PRR-E
			Totals		112597	759.30	125	5	4	34	176	23.8	
1916	80	ASCE	.55	.66	1042	8.29	-	-	-	-	-	0.0	MM&SE
	80	Dudley	.55	.68	20049	159.49	1	-	1	3	5	3.1	NYC-E
	85	ASCE			1500	11.23	-	-	-	-	-	0.0	A A
	85	ASCE	.62	.75	15620	116.94	-	-	1	1	2	1.7	B&M
	90	ARA-A	.62	.75	5000	35.35	2	-	-	-	2	5.7	CB&Q
	90	ARA-A	.59	.72	6029	42.63	-	-	-	-	-	0.0	CM&StP
	90	GN	.59	.72	9136	64.60	2	-	-	-	2	3.1	G N
	90	ARA-B	.59	.72	5496	38.87	1	1	-	-	2	5.1	N P
	90	Dudley	.60	.73	1414	10.00	-	-	-	-	-	0.0	Rutland
	100	NYNH&H	.62	.75	9785	62.27	5	-	1	-	6	9.6	B&M
	100	ASCE			3294	33.69	10	-	1	1	12	35.6	BR&P
	100	ARA-A	.62	.75	5185	33.00	11	2	-	1	14	42.4	Erie
	105	Dudley	.62	.75	8400	50.91	10	-	-	-	10	19.6	B&A
	105	DL&W	.64	.77	5130	31.09	1	1	-	-	2	6.4	DL&W
	105	Dudley	.62	.75	27971	169.52	2	-	-	-	2	1.2	NYC-E
	105	Dudley	.62	.75	4710	28.55	2	-	-	-	2	7.0	NYC-W
	125	PS	.68	.82	10205	51.94	22	1	-	-	23	44.3	PRR-E
			Totals		141966	948.37	69	5	4	6	84	8.9	
1917	80	Dudley	.55	.68	19605	155.96	1	-	-	2	3	1.9	NYC-E
	85	ASCE			1500	11.23	-	-	-	-	-	0.0	A A
	90	GN	.59	.72	2777	19.63	-	-	-	-	-	0.0	G N
	90	ARA-B	.59	.72	4789	33.86	-	-	-	-	-	0.0	N P
	90	Dudley	.60	.73	1748	12.36	-	-	-	-	-	0.0	Rutland
	100	NYNH&H	.62	.75	7150	45.50	-	-	-	-	-	0.0	B&M
	100	P&R	.67	.80	3011	19.16	1	-	-	-	1	5.2	P&R
	105	Dudley	.62	.75	8400	50.91	-	-	-	-	-	0.0	B&A
	105	DL&W			7841	47.52	-	-	-	-	-	0.0	DL&W
	105	Dudley	.62	.75	10000	60.60	-	-	-	-	-	0.0	NYC-W
	105	Dudley	.62	.75	30737	186.29	1	-	-	-	1	0.5	NYC-E
			Totals		97558	643.01	3	-	-	2	5	0.8	

Table 7, Sheet 13

Total Rail Failures From Date Rolled to October 31st, 1917.

Year Rolled	Lbs Per Yd.	Section	Specified Carbon Min	Specified Carbon Max	Total Tons Laid	Equiv Track Miles	Failures to Date: Head	Web	Base	Brkn	Total	Per 100 Trk Mls	Railroad
Open Hearth - Lorain Steel Company													
1912	100	PS	.62	.75	3919	24.94	5	-	-	2	7	28.1	PR-W-[illegible]
Open Hearth - Maryland Steel Company													
1912	85	ASCE	.55	.68	4650	34.81	2	-	-	1	3	8.6	ACL
	85	ASCE	.65	.78	8000	59.89	7	-	10	63	80	133.6	McC
	100	PS	.62	.75	1285	8.18	12	10	-	9	31	379.0	PRR-E
			Total		13935	102.88	21	10	10	73	114	110.8	
1913	80	ASCE	.58	.71	3466	27.57	-	-	-	1	1	3.9	NYNH&H
	85	ASCE	.55	.68	5950	44.55	-	-	-	2	2	4.5	ACL
	85	ASCE	.62	.75	2011	15.06	2	-	-	6	8	53.1	N&W
	85	Dudley			3755	28.11	2	-	1	-	3	10.7	SAL
	90	ARA-B	.63	.76	2624	18.55	14	-	-	8	22	118.6	B&O
	90	ARA-A	.59	.72	1948	13.77	-	-	3	1	4	29.1	CM&StP
	90	ARA-A			1552	10.97	1	3	-	-	4	36.5	SAL
	90	ARA-A			15066	106.56	11	2	1	2	16	20.4	S P
	100	ARA-B	.63	.76	17576	111.85	179	9	6	101	295	263.7	B&O
	100	NYNH&H	.65	.78	1006	6.41	1	-	-	1	2	31.3	NYNH&H
	100	ARA-B	.62	.75	5622	35.77	56	-	-	5	61	170.5	N&W
	100	PS	.62	.75	7686	48.91	47	29	5	38	119	243.3	PRR-E
	100	ARA-B	.63	.67	1001	6.37	7	5	1	5	18	282.6	Virg'n
			Totals		69263	474.45	320	48	17	170	555	117.0	
1914	80	ASCE	.53	.66	2986	23.75	-	-	-	-	-	0.0	NYNH&H
	85	ASCE	.55	.68	17900	134.01	-	-	-	1	1	0.7	ACL
	85	ASCE	.62	.75	2764	20.69	1	-	-	-	1	4.8	N&W
	90	ARA-A	.59	.72	1972	13.94	-	-	-	1	1	7.2	CM&StP
	90	ARA-A	.62	.75	4985	35.24	-	-	-	-	-	0.0	SAL
	100	NYNH&H	.63	.76	1572	10.00	-	-	-	1	1	10.0	B&M
	100	PS	.62	.75	3100	19.73	-	-	-	-	-	0.0	C V
	100	ARA-B	.62	.75	4050	25.77	2	-	-	1	3	11.6	N&W
	100	PS	.60	.75	3298	20.99	6	2	-	-	8	38.1	PRR-E
	100	PS	.62	.75	10923	69.51	16	4	-	7	27	38.8	PRR-I
	100	PS	.62	.75	11854	75.51	55	22	1	6	84	111.6	PRR-E
	100	ARA-B	.63	.67	1403	8.93	10	6	1	1	18	201.6	Virg'n
			Totals		66787	457.87	90	34	2	18	144	31.5	
1915	85	ASCE	.62	.75	2702	20.23	-	-	-	-	-	0.0	N&W
	100	ARA-B	.62	.75	4328	27.54	3	-	2	4	9	32.7	B&O
	100	ARA-B	.62	.75	3356	21.35	4	1	-	3	8	37.5	N&W
	100	PS	.60	.75	13055	83.08	53	9	5	29	96	115.6	PRR-E
	100	ASCE			1000	6.36	-	-	-	-	-	0.0	NP&P
	107	NYNH&H,	.62	.75	10831	64.42	2	-	-	1	3	4.7	NYNH&H
	125	PS	.68	.82	11324	57.65	51	1	-	1	53	91.9	PRR-E
			Totals		46596	280.63	113	11	7	38	169	60.2	
1916	85	Dudley	.62	.75	4556	34.11	-	2	-	-	2	5.9	SAL
	90	ARA-A	.59	.72	1999	14.13	-	-	-	1	1	7.1	CM&StP
	100	ARA-B	.62	.75	11607	73.86	46	3	3	23	75	101.5	B&O
	100	PS	.60	.75	2188	13.92	-	-	-	-	-	0.0	C V
	100	ARA-B	.62	.75	4001	25.46	1	1	-	-	2	7.9	N&W
	100	P&R	.67	.80	2852	18.14	-	-	-	1	1	5.5	P&R
	x107	NYNH&H	.62	.75	4593	26.13	-	-	-	2	2	7.7	NYNH&H
	125	PS	.68	.82	24252	123.36	14	1	2	1	18	14.6	PRR-E
			Totals		[illegible]	329.11	61	7	5	28	101	30.7	
1917	85	Dudley	.62	.75	1332	9.97	-	-	-	-	-	0.0	SAL
	90	ARA-A	.59	.72	2394	16.93	-	-	-	-	-	0.0	CM&StP
	90	ARA-A	.62	.75	6931	49.01	1	2	-	9	12	24.5	SAL
	100	ARA-B	.62	.75	5000	31.82	4	3	-	1	8	25.1	N&W
	100	P&R	.67	.80	7090	45.11	34	6	-	17	57	126.4	P&R
	100	ASCE	.59	.72	1500	9.55	-	-	-	-	-	0.0	NP&P
	100	ARA-B	.62	.76	4509	28.69	7	4	1	2	14	48.8	Virg'n
	107	NYNH&H	.62	.75	2755	16.38	-	-	-	-	-	0.0	NYNH&H
	125	PS	.68	.82	5380	27.35	19	-	1	4	24	87.8	PRR-E
			Totals		36891	234.79	65	15	2	33	115	49.0	

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Table 7, Sheet 1

Total Rail Failures From Date Rolled to October 31st, 1917.

Year Rolled	Lbs Per Yd.	Section	Specified Carbon Min	Specified Carbon Max	Total Tons Laid	Equiv Track Miles	Failures to Date Head	Web	Base	Brkn	Total	Per 100 Trk Mls	Railroad
					Open Hearth - Pennsylvania Steel Company								
1912	72	NP	.52	.65	1757	13.55	-	-	-	1	1	6.4	N P
	85	ASCE	.55	.68	5990	44.85	-	3	-	1	4	8.9	ACL
	85	ASCE	.62	.75	4485	33.58	2	2	-	13	17	50.6	N&W
	90	GN	.59	.72	24148	170.75	7	5	37	116	165	96.6	G N
	90	ASCE	.67	.80	6504	45.98	4	5	-	15	24	52.2	P&R
	100	ARA-A	.70	.85	6575	40.56	2	-	1	3	6	14.8	CNJ
	100	PS			2071	13.18	1	-	-	3	4	30.4	C V
	100	ARA-B	.62	.75	2175	13.84	1	-	-	3	4	28.9	N&W
	100	ARA-B	.62	.75	2048	13.03	1	-	13	14	28	214.9	N P
	100	PS	.62	.75	5187	33.01	14	6	-	7	27	81.8	PRR-E
	100	P&R	.67	.80	9951	65.32	8	5	-	12	25	38.3	P&R
	101	DL&W	.62	.75	2202	13.87	-	-	-	-	-	0.0	DL&W
			Totals		72891	501.80	40	24	51	188	305	60.4	
1913	72	NP	.52	.65	2984	26.37	-	-	-	1	1	3.8	N P
	80	ASCE	.65	.78	1005	8.00	-	-	2	1	3	37.5	CNE
	80	ASCE	.58	.71	1265	10.06	-	-	-	1	1	9.9	NYNH&H
	85	ASCE	.55	.68	1010	7.56	-	-	-	-	-	0.0	ACL
	90	GN	.58	.72	4882	34.52	15	5	8	22	50	144.9	G N
	90	ARA-B	.62	.75	1045	7.38	-	-	3	4	7	94.7	N P
	90	ARA-B	.59	.72	10442	73.82	11	-	8	7	26	35.2	N P
	100	NYNH&H	.65	.76	3550	22.59	-	1	3	1	5	22.1	B&M
	100	ARA-A	.70	.85	3883	24.70	6	5	2	20	35	141.7	CNJ
	100	PS			1536	9.77	1	-	-	-	1	10.2	C V
	100	ARA-A	.63	.76	10506	65.58	51	-	3	6	60	91.5	L V
	100	NYNH&H	.65	.76	11758	74.70	5	4	5	7	21	28.1	NYNH&H
	100	ARA-B	.62	.75	1904	12.12	-	-	-	7	7	57.8	N P
	100	PS	.62	.75	10192	64.86	6	6	-	11	23	35.5	PRR-E
	100	P&R	.67 **	.80 **	18988	120.85	12	2	-	7	21	17.4	P&R
	101	DL&W			7980	50.28	4	7	-	3	14	27.8	DL&W
	135	CNJ	.90	1.05	2287	13.61	19	1	-	1	21	154.3	CNJ
			Totals		96896	626.75	132	31	34	99	296	47.2	
1914	75	B&M	.55	.63	1980	16.29	-	-	-	6	6	36.8	B&M
	85	ASCE	.65	.76	1490	11.16	1	-	-	-	1	9.0	B&M
	90	GN	.59	.72	2130	15.06	-	1	-	3	4	26.6	G N
	90	ARA-B	.59	.72	3192	22.57	3	-	3	5	11	48.7	N P
	90	ASCE	.67	.80	1008	7.09	-	-	-	2	2	28.2	P&R
	100	ARA-A	.70	.85	4600	29.27	-	-	-	-	-	0.0	CNJ
	100	NYNH&H	.65	.76	4894	31.14	1	1	1	3	6	19.3	NYNH&H
	100	PS	.62	.75	5288	33.65	7	2	-	8	17	50.5	PRR-E
	100	P&R	.67 **	.80 **	5526	35.16	1	2	-	1	4	11.4	P&R
	101	DL&W	**	**	4576	27.57	6	8	-	4	18	65.3	DL&W
	105	DL&W			4515	27.35	3	4	1	-	8	29.3	DL&W
	135	CNJ	.90	1.05	1108	5.20	-	-	-	-	-	0.0	CNJ
			Totals		40035	241.51	22	18	5	32	77	29.4	
1915	90	ARA-A	.59	.72	1000	7.07	-	-	-	-	-	0.0	CB&Q
	90	ASCE	.67	.80	1996	14.11	2	5	-	3	10	70.9	P&R
	100	PS	.60	.75	3479	22.14	-	-	-	-	-	0.0	C V
	100	PS	.60	.75	1018	6.48	-	-	-	-	-	0.0	PRR-E
	100	P&R	.67	.80	5294	33.69	8	-	-	4	12	35.6	P&R
	100	ARA-B	.65 **	.67 **	1350	8.59	2	1	-	-	3	34.9	Virg'n
	105	DL&W			6754	40.81	-	-	-	-	-	0.0	DL&W
	125	PS	.78	.92	3529	27.13	3	1	-	-	4	14.7	PRR-E
			Totals		26800	160.02	15	5	-	9	29	18.1	
1916	105	P&R	.67 **	.80 **	4587	29.19	9	-	-	8	17	58.2	P&R
	105	DL&W			3063	18.56	-	-	-	-	-	0.0	DL&W
			Totals		7650	47.75	9	-	-	8	17	35.6	
1917	85	ASCE	.62	.75	8250	61.76	-	-	-	-	-	0.0	B&M
					Open Hearth - Tennessee Coal, Iron & Railroad Company								
1912	75	AREA	.55	.68	3000	25.45	-	-	-	-	-	0.0	A B
	75	CS	.55	.68	1125	9.55	-	-	-	-	-	0.0	GH&SA
	75	CS-R	.55	.68	6942	58.80	-	-	-	-	-	0.0	H&TC
	75	CS	.55	.68	7307	61.98	-	-	-	1	1	1.6	HE&WT
	75	ASCE	.65	.76	1299	11.02	1	-	-	-	1	9.1	I C
	75	ASCE			12004	101.96	1	-	-	-	1	1.0	I&GN
	75	CS			2209	18.75	-	-	-	-	-	0.0	MD&S
	75	CS-R	.65	.76	6745	57.25	1	-	-	-	1	1.7	OSL
	80	ASCE	.58	.71	1800	14.32	9	12	4	12	37	258.4	CofGa
	80	ASCE			1046	8.32	-	-	-	-	-	0.0	Ga
	80	ASCE	.55	.68	10266	81.66	53	12	6	7	78	95.5	L&N
	80	ASCE	.55	.65	3185	25.32	-	-	-	-	-	0.0	NYC&StL
	85	ASCE	.55	.68	11980	89.69	5	3	1	7	16	17.9	ACL
	85	ASCE			5540	39.97	-	-	-	-	-	0.0	MK&T
	85	ASCE	.55	.65	7065	52.88	6	18	10	12	46	87.0	NC&StL
	85	ASCE	.59	.72	5610	42.05	17	3	1	15	35	83.2	StL-SF
	85	Dudley	.62	.75	6128	45.87	3	13	17	12	45	98.1	SAL
	85	ASCE	.59	.72	28506	213.37	140	45	25	39	249	116.7	Southern
	90	SF	.65	.76	8735	61.75	20	1	-	3	24	38.8	AT&SF
	90	ARA-A	.58	.71	2000	14.14	11	2	4	10	27	190.9	CofGa
	90	ARA-A	.65	.76	1727	12.21	10	-	-	7	17	139.2	GH&SA
	90	ARA-A	.63	.76	17286	122.22	156	16	173	119	464	379.6	I C
	90	ARA-B	.60	.75	31465	222.47	75	25	6	52	158	71.0	L&N
	90	ASCE	.59	.72	13000	91.91	8	2	4	21	35	38.1	StL-SF
	90	ARA-A			2822	19.95	4	10	1	1	16	80.2	S P
			Totals		198524	1402.91	540	141	252	318	1251	89.2	

** Note - Rail Rolled under Physical Test, without limits to Chemistry except Phosphorus.
Carbon of Heats accepted in 1913 varied between .60 and .75
Carbon of Heats accepted in 1914 varied between .59 and .75
Carbon of Heats accepted in 1915 varied between .58 and .70
Carbon of Heats accepted in 1916 varied between .65 and .75

Table 7, Sheet 15

Total Rail Failures From Date Rolled to October 31st, 1917.

Year Rolled	Lbs Per Yd.	Section	Specified Carbon Min	Specified Carbon Max	Total Tons Laid	Equiv Track Miles	Failures to Date: Head	Web	Base	Brkn	Total	Per 100 Trk Mls	Railroad
				Open Hearth - Tennessee Coal, Iron & Railroad Company - Cont'd.									
1913	75	CS-R	.55	.68	2700	22.91	-	-	-	-	-	0.0	A B
	75	CS-R	.55	.68	5835	49.49	-	-	-	1	1	2.0	GH&SA
	75	CS-R	.55	.68	1121	9.51	-	-	-	-	-	0.0	H&TC
	75	ASCE	.50	.63	2575	21.85	-	-	-	-	-	0.0	T&P
	80	ASCE	.58	.71	5300	42.16	6	3	-	1	10	23.7	CofGa
	80	ASCE			1609	12.80	-	-	-	-	-	0.0	Ga.
	80	ASCE	.55	.66	9251	73.59	15	3	1	6	25	34.0	L&N
	80	ASCE	.55	.65	2456	19.59	-	-	-	-	-	0.0	NC&StL
	85	ASCE	.55	.68	14940	111.85	-	3	-	3	6	5.4	ACL
	85	ASCE	.59	.72	1456	10.90	3	2	-	1	6	55.1	CC&O
	85	ASCE			1228	9.19	-	1	-	-	1	10.9	M&O
	85	ASCE	.55	.65	6680	50.00	-	-	1	1	2	4.0	NC&StL
	85	Dudley	.59	.75	11682	87.45	23	-	13	10	46	52.6	SAL
	85	ASCE	.59	.72	35088	262.66	93	14	12	20	139	52.9	Southern
	85	ASCE	.55	.68	11179	83.69	5	-	-	2	7	8.4	T&P
	90	ARA-A	.63	.76	1830	12.94	76	-	-	-	76	587.3	A B
	90	ARA-A	.58	.71	2200	15.56	16	-	1	3	20	128.6	CofGa.
	90	ARA-A	.63	.76	8562	60.54	2	-	-	2	4	6.6	GH&SA
	90	ARA-A	.63	.76	10947	77.40	-	-	-	-	-	0.0	H&TC
	90	ARA-A	.63	.76	37801	267.28	169	11	16	35	231	86.4	I C
	90	ARA-B	.63	.76	56719	401.05	81	36	9	50	176	43.9	L&N
	90	ARA-A	.59	.72	3117	22.04	1	-	-	4	5	22.7	M P
	90	ARA-A	.63	.76	4848	34.28	-	-	-	-	-	0.0	MLT
	90	ARA-A	.55	.65	8063	57.01	14	1	5	3	23	40.3	NC&StL
	90	ASCE	.62	.75	5800	41.01	7	2	-	4	13	31.7	StL-SF
	90	ARA-A	.63	.76	7072	50.00	1	-	1	-	2	4.0	T&NO
		Totals			260057	1906.51	512	76	59	146	793	41.6	
1914	75	CS-R	.55	.68	3254	27.44	-	-	-	-	-	0.0	A B
	80	ASCE	.58	.71	4537	36.09	1	-	-	3	4	11.1	CofGa
	80	ASCE	.53	.66	7027	55.90	8	-	-	1	9	16.1	L&N
	80	ASCE	.55	.65	2512	19.98	1	-	-	-	1	5.0	NC&StL
	85	ASCE	.56	.65	15750	117.92	-	-	-	1	1	0.8	ACL
	85	ASCE			2976	22.28	4	-	-	4	8	35.9	M&O
	85	Dudley	.59	.72	1408	10.54	-	-	-	2	2	19.0	SAL
	85	ASCE	.59	.72	35837	268.56	125	12	10	10	157	58.5	Southern
	90	ARA-A	.63	.76	6237	44.10	2	-	-	-	2	4.5	GH&SA
	90	ARA-A	.63	.76	2025	14.28	2	-	-	-	2	14.0	H&TC
	90	ARA-A	.63	.76	24773	175.16	77	10	7	16	110	62.8	I C
	90	ARA-A	.63	.76	2687	19.00	-	-	-	-	-	0.0	L&W
	90	ARA-B	.63	.76	80914	572.11	119	25	4	21	169	29.5	L&N
	90	ARA-A	.59	.72	4427	31.30	-	-	-	1	1	3.2	M P
	90	ARA-A	.55	.65	3931	27.79	3	1	-	-	4	14.4	NC&StL
	90	ASCE	.62	.75	42450	300.10	13	15	10	28	66	22.0	StL-SF
	90	ARA-A			1609	11.38	-	-	-	-	-	0.0	S P
	90	ARA-A			16598	117.37	4	1	-	1	6	5.1	S P
		Totals			258932	1871.14	359	64	31	88	542	29.0	
1915	80	ASCE	.58	.71	2004	15.94	2	2	-	-	4	25.1	CofGa.
	80	ASCE	.55	.65	3000	23.87	11	-	1	1	13	54.5	NC&StL
	85	ASCE	.55	.68	6300	47.17	-	-	-	-	-	0.0	ACL
	85	ASCE	.59	.72	1200	8.98	5	-	-	1	6	66.8	CC&O
	85	ASCE			1818	13.61	-	-	-	1	1	7.3	M&O
	85	ASCE	.59	.72	30254	226.54	33	4	3	9	49	21.6	Southern
	90	ARA-A	.63	.76	11221	79.34	4	-	-	-	4	5.0	GH&SA
	90	ARA-A	.63	.76	4584	32.41	-	-	-	-	-	0.0	H&TC
	90	ARA-A	.63	.76	3479	24.60	9	3	1	-	13	52.8	I C
	90	ARA-A	.63	.76	1400	9.90	-	-	-	-	-	0.0	L&W
	90	ARA-B	.62	.75	39692	280.69	28	11	2	5	46	16.4	L&N
	90	ARA-A	.59	.72	10865	76.82	-	-	-	-	-	0.0	M P
	90	ARA-A	.62	.75	2989	21.14	4	-	-	-	4	18.9	NC&StL
	90	ASCE	.62	.75	20510	145.10	4	3	8	6	21	14.5	StL-SF
		Totals			139308	1005.91	100	23	15	23	161	16.0	
1916	80	ASCE	.53	.66	4140	32.93	1	1	-	-	2	6.1	CofGa.
	80	ASCE	.53	.66	1838	14.62	2	-	1	-	3	20.5	L&N
	85	ASCE	.59	.72	20000	149.73	-	-	1	-	1	0.7	ACL
	85	ASCE	.59	.72	2088	15.65	9	-	-	3	12	76.8	CC&O
	85	Dudley	.59	.72	7206	53.94	3	-	-	1	4	7.4	SAL
	85	ASCE	.59	.72	8821	66.14	14	3	3	7	27	40.8	Southern
	85	ASCE	.59	.72	1836	13.74	1	-	-	1	2	14.6	T&P
	90	ARA-A	.62	.75	1756	12.42	5	-	-	-	5	40.3	CofGa.
	90	ARA-A	.63	.76	30968	218.96	14	-	-	-	14	6.4	GH&SA
	90	ARA-A	.63	.76	3688	26.08	1	-	-	-	1	3.8	H&TC
	90	ARA-A	.63	.76	12051	85.21	14	13	-	-	27	31.7	I C
	90	ARA-A	.65	.76	1417	10.02	-	-	-	-	-	0.0	L&W
	90	ARA-B	.62	.75	39610	280.07	16	15	1	10	42	15.0	L&N
	90	ARA-A	.62	.75	2834	20.04	-	-	-	-	-	0.0	M P
	90	ARA-A	.62	.75	7321	51.76	6	3	-	-	9	17.4	NC&StL
	90	ASCE	.62	.75	15960	112.90	8	3	3	1	15	13.3	StL-SF
	90	ARA-A	.59	.72	1141	8.07	23	-	-	-	23	285.0	SAL
	90	ARA-A			4940	34.93	1	-	-	-	1	2.9	S P
		Totals			167632	1207.19	118	38	9	23	188	15.6	
1917	85	ASCE	.59	.72	5700	42.67	-	-	-	-	-	0.0	ACL
	85	ASCE	.59	.72	36141	270.32	6	2	-	-	8	3.0	Southern
	85	ASCE	.59	.72	5676	42.49	-	-	-	-	-	0.0	T&P
	90	ARA-A	.62	.75	10000	70.71	1	-	-	-	1	1.4	CofGa.
	90	ARA-A	.63	.76	1365	9.64	-	-	-	-	-	0.0	GH&SA
	90	ARA-A	.63	.75	7897	55.84	1	-	-	3	4	7.2	I C
	90	ARA-B	.62	.75	32995	235.20	2	4	2	5	13	5.6	L&N
	90	ARA-A	.59	.72	12027	85.02	-	-	-	-	-	0.0	SAL
		Totals			111799	808.89	10	6	2	8	26	3.2	

Appendix F.

TRANSVERSE FISSURE RAILS ON DELAWARE, LACKAWANNA & WESTERN RAILROAD—HEAT 27314

By M. H. Wickhorst, Engineer of Tests, Rail Committee.

This report gives the results of an examination of a heat of rails on the Delaware, Lackawanna & Western Railroad, which was removed from service on account of four rails failing and showing transverse fissures. The record of the four rails which failed in track is given in Table 1. We are unable to say whether the fissures in these rails were simple transverse fissures or were of the compound type in which the transverse part is a branch or growth from a longitudinal fissure, as unfortunately neither the rails nor photographs of the fractures were available at the time of making this investigation.

Table 1—Failed Rails.

	1	2	3	4
Rail Letter	E	E	Unknown	D
Date Laid	11-1914	11-1914	11-1914	11-1914
Date Removed	9-1916	9-1916	11-1916	12-1916
Age	1 y. 10 m.	1 y. 10 m.	2 yrs.	2 yrs. 2 m.
Mile Post	35	35	32	35
Curvature	2°	2°	2½°	2°
High or Low Rail	low	low	low	low
Grade, ft. per mi.	33	33	42	33

The rails were of the D. L. & W. 105 lb. section made in November, 1914, at the Bethlehem plant of the Bethlehem Steel Company, and were all removed from track in February, 1917. Through the kindness of G. J. Ray, Chief Engineer, and H. J. Force, Engineer of Tests, of the D. L. & W. R. R., the rails were gathered together at Scranton, Pa., and an investigation made of them by means of bending tests, chemical analyses and tensile tests.

The rails were of heat number 27314 and were branded Bethlehem 105C XI 1914. In the original inspection of the rails, the A rails failed in the drop test and were rejected, and therefore no A rails are included in this investigation. Ninety-nine rails had been gathered at Scranton and it was intended to test all of them, but through misunderstanding most of the rails had been taken for secondary track work before the actual testing could be started, leaving 25 rails covered by this report. From out of the middle of each rail a piece 15 inches long was cut by means of an oxygen-acetylene torch for chemical analyses and tensile tests. The two long pieces were used for bending tests to disclose any fissures present in them.

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TABLE 2—BENDING TESTS.

Rail Letter	Rail Numbers	Number of Breaks: With Fissures	Interior	From Top	Uncertain	Total
B	1	..	9	1	..	10
B	2	..	10	..	..	10
B	6	..	..	..	..	..
B	21	..	7	1	..	8
	4 rails	0	26	2	0	28
C	3	..	3	5	..	8
C	7	..	6	2	..	9
C	9	..	1	..	..	1
C	15	..	9	..	..	9
C	18	..	10	..	..	10
C	23	..	5	..	1	6
	6 rails	0	34	7	1	43
D	4	..	3	..	..	3
D	5	..	1	3	1	5
D	10	1	1	..	..	2
D	11	..	..	..	..	..
D	25	..	..	1	..	1
	5 rails	1	5	4	1	11
E	19	..	..	..	..	..
E	20	..	..	..	..	..
	2 rails	0	0	0	0	0
F	8	..	2	..	..	2
F	12	..	..	..	..	..
F	13	..	..	3	1	4
F	17	..	..	1	..	1
F	22	..	2	..	..	2
F	24	4	4	..	1	9
F	26	..	5	..	..	5
	7 rails	4	13	4	2	23
All.......	24 rails	5	78	17	4	104

Bending Tests.

The long pieces of rail were subjected to bending in a hydraulic press with the head down so as to put this part in tension. The supports were four feet apart and the rails were bent at intervals of about two feet along their length. If the rail did not break it received a camber of eight inches or more in the half rail length; that is, the middle ordinate from a cord stretched between the ends of the rail, to the base, was a minimum of eight inches. The results of the bending tests are given in Table 2, grouped by ingot positions of the rails. The heading of the column entitled "Interior," means that the initial point of break was in the interior of the head, as evidenced by the fracture lines radiating from a point inside the head, generally near the middle. The heading "From Top" means that the fracture lines radiated from a point at the top surface of the head, thus indicating the initial point of the break. In these cases the steel showed a very fine-grained, hardened structure for

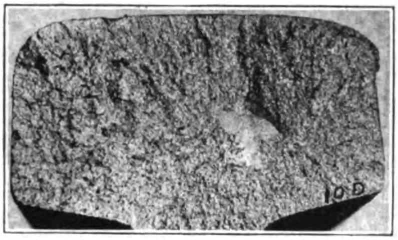

Fig. 1—Fissure Found in D Rail Number 10.

a depth of about $\frac{1}{16}$ inch from the surface, due presumably to driver slippage. The heading "Uncertain" means that the initial point of break could not be definitely determined from the appearance of the fracture.

It will be noted that fissures were found in two of the 24 rails listed; one fissure in D rail number 10 and four fissures in E rail number 24. The fissure found in rail 10 is shown in Fig. 1 and the four fissures found in rail 24 are shown in Fig. 2. The four fissures of rail 24 were of the simple transverse fissure type in which the fissure developed transversely from a granular core. The fissure of rail 10, however, is seen to have evidently been the transverse branch of a compound fissure in which the main part was longitudinal and obliquely horizontal.

Of the 104 breaks, it will be noted that 78 started in the interior of the head, in addition to the 5 breaks that showed fissures. Seventeen started at the top surface in metal that had been hardened by driver slippage, but it is interesting to note that cracks had not developed in service from this hardened metal so far as disclosed by this examination.

In addition to the rails listed in the table, there was one rail (num-

ber 16) on which the rail letter or ingot position could not be recognized. This gave three breaks, all from the top surface.

CHEMICAL ANALYSES.

Two samples were taken for analysis from near the middle of each rail, one from the O position (outside), near an upper corner of the

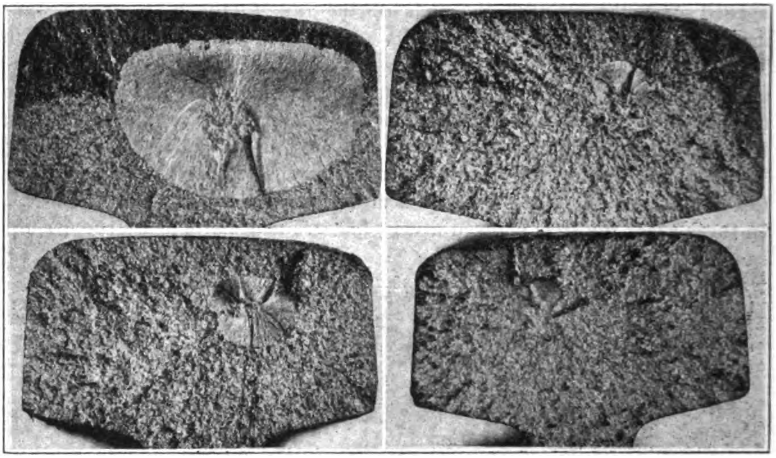

FIG. 2—FOUR FISSURES FOUND IN RAIL NUMBER 24.

head, and the other from the M position (middle), from the interior of the head near the web, as shown in Fig. 3. On each sample determinations were made of carbon, manganese, phosphorus, sulphur and silicon,

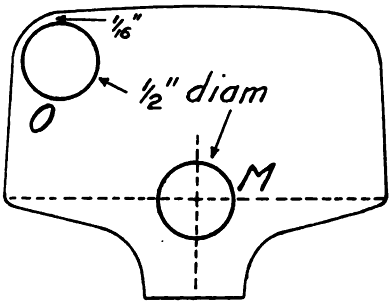

FIG. 3—LOCATIONS OF SAMPLES FOR ANALYSES.

and the results are given in Table 3, grouped by ingot position of the rails. The average composition of the steel as poured would be fairly well represented by the average of the samples from the O position, and these results are given below in comparison with the original heat analysis

by the mill and the analysis of a sample of rail by the Railroad Company at the time of inspection of the rails.

	C	*Mn*	*P*	*S*	*Si*
Average all rails.......	.761	.83	.026	.026	.170
Ladle analysis	.742	.99	.022	0.24	.154
Inspected rail	.738	.98	.022	.024	.154

TABLE 3—CHEMICAL ANALYSES.

Rail Letter	Rail No.	O Position					M Position					Carb Seg. %
		C	Mn	P	S	Si	C	Mn	P	S	Si	
B	1	.754	.80	.034	.026	.173	.832	.80	.028	.029	.178	10.3
B	2	.750	.80	.028	.026	.172	.778	.80	.028	.027	.176	3.7
B	6	.762	.80	.026	.026	.188	.748	.80	.025	.026	.185	—1.8
B	21	.760	.86	.029	.028	.179	838	.87	029	031	183	10.3
Average..	....	.757	.82	.029	.027	.178	.799	.82	.028	.028	.181	5.5
C	3	.770	.80	.025	.026	.188	.776	.80	.027	.028	.183	0.8
C	7	.768	.80	.026	.026	.183	.760	.81	.026	.026	.179	—1.0
C	9	.766	.86	.021	.018	.160	.742	.72	.023	.027	.166	—3.1
C	15	.760	.94	.021	.018	.178	.768	.95	.024	.028	.171	1.1
C	18	.764	.89	.029	.024	.199	.768	.89	.026	.025	.195	0.5
C	23	.756	.81	.026	.026	.178	.774	.82	.026	.027	.184	2.4
Average..	....	.764	.85	.025	.023	.181	.765	.83	.025	.027	.180	0.1
D	4	.772	.78	.031	.026	.155	.734	.78	.030	.026	.157	—4.9
D	5	.772	.80	.031	.026	.172	.752	.80	.028	.026	.169	—2.6
D	10	.742	.77	.020	.037	.150	.720	.85	.024	.031	.152	—3.0
D	11	.760	.85	.023	.034	.178	.730	.85	.023	.028	.169	—3.9
D	25	.768	.90	.022	.031	.155	.720	.86	.021	.026	.148	—6.2
Average..	....	.763	.82	.025	.031	.162	.731	.83	.025	.027	.159	—4.2
E	19	.762	.83	.022	.032	.169	.788	.87	.022	.029	.166	3.4
E	20	.738	.85	.023	.030	.155	.714	.86	.021	.018	.160	—3.3
Average..	....	.750	.84	.023	.031	.162	.751	.87	.022	.024	.163	0.1
F	8	.754	.82	.025	.027	.192	.712	.80	.023	.025	.186	—5.6
F	12	.756	.80	.033	.025	.148	.712	.80	.030	.026	.152	—5.7
F	13	.758	.81	.033	.027	.162	.726	.78	.031	.027	.158	—4.2
F	17	.766	.81	.026	.027	.162	.714	.80	.026	.026	.160	—6.8
F	22	.754	.92	.025	.017	.152	.708	.86	.027	.030	.155	—6.1
F	24	.766	.82	.023	.018	.164	.708	.83	.021	.022	.155	—7.6
F	26	.782	.87	.023	.028	.176	.720	.86	.025	.026	.181	—7.9
Average..	....	.762	.84	.027	.024	.165	.714	.82	.026	.026	.164	—6.3
Gen. Average.....		.761	.83	.026	.026	.170	.748	.83	.026	.027	.170	—1.7

It will be noted that except as to manganese these several results are in fair agreement.

For convenience of comparison the average carbon results for the several ingot positions are collected together in Table 4.

TABLE 4—AVERAGE CARBON RESULTS.

Rail Letter	Number of Rails	O Position	M Position	Segregation Per Cent
B	4	·757	·799	5·5
C	6	·764	·765	0.1
D	5	·763	·731	—4.2
E	2	·750	·751	0.1
F	7	·762	·714	—6.3
All:........	24	.761	.748	—1.7

It will be noted that in the O position or the corner of the head the carbon was about the same in the several ingot positions; in the M position or interior of the head the carbon decreased downward of the ingot. This is the normal distribution of carbon in the ingot.

TENSILE TESTS.

Two specimens were cut for tensile tests from near the middle of each rail, one from the O position and the other from the M position, as shown in Fig. 4. The specimens were one-half inch in diameter for

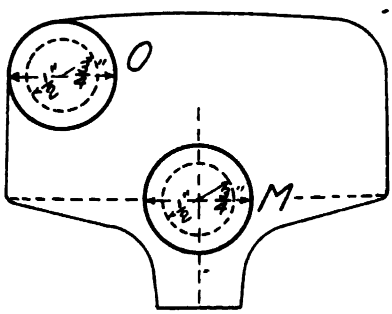

FIG. 4—LOCATIONS OF SPECIMENS FOR TENSILE TESTS.

a gage length of two inches. The results of the tests are given in Table 5, grouped by ingot position of the rails. In the table, the yield point and tensile strength are expressed in pounds per square inch, the elongation is the per cent. of stretch in two inches and the reduction of area is the per cent. reduction of the original cross-section.

It will be noted that in the O position, or corner of the head, the metal showed good tensile properties; the tensile strength and elongation were good in all the samples. In the M position, or interior of the head, however, there was considerable variation in tensile properties; the elongation was good in most of the D, E and F rails, but in most of the B and C rails the elongation was low or almost absent. D rail number 10,

TABLE 5—TENSILE TESTS.

Rail Letter	Rail No.	O Position				M Position			
		Yl. Pt.	Tens. Str.	Elong.	Red.	Yl. Pt.	Tens. Str.	Elong.	Red.
B	1	95050	139600	13.0	19.0	94200	103700	3.0	2.8
B	2	88760	134700	12.5	17.3	94750	135800	10.0	12.8
B	6	109700	137300	12.0	18.6	93230	135700	9.5	14.6
B	21	93330	135100	12.5	16.1	broke short	....	......	....
Average....		96710	136675	12.5	17.8	94060	125067	7.5	10.1
C	3	94580	141000	12.0	18.9	92070	114400	5.0	5.4
C	7	96400	134200	12.5	19.1	93610	133300	8.0	4.3
C	9	94450	134900	12.0	16.7	106900	135200	11.0	13.6
C	15	94700	133200	11.0	18.6	94700	99800	1.5	2.0
C	18	94130	136500	12.5	18.3	broke short	....	......	....
C	23	94960	133400	13.0	17.6	94000	97300	2.0	1.6
Average....		94870	135533	12.2	18.2	96256	116000	5.5	5.4
D	4	95060	132200	11.0	15.7	93100	126300	11.0	11.7
D	5	92500	133100	12.0	17.6	91060	127400	11.5	17.6
D	10	92600	134100	12.0	18.3	96800	127900	12.0	15.1
D	11	88900	131000	12.0	17.9	86750	130500	11.5	15.3
D	25	101600	136870	12.5	17.3	96000	127400	12.0	16.8
Average....		94132	133454	11.9	17.4	92742	127900	11.6	15.3
E	19	99600	135900	11.0	17.1	90400	133900	5.5	5.5
E	20	88700	135100	10.0	17.2	86950	129600	10.5	17.2
Average....		94150	135500	10.5	17.2	88675	131750	8.0	11.4
F	8	95820	132700	12.0	15.7	88130	126200	13.5	19.0
F	12	95010	137200	11.5	20.8	93740	129600	11.5	19.3
F	13	95920	132700	12.5	17.6	94250	131300	9.5	13.9
F	17	93660	136200	13.0	17.9	91620	130500	12.5	17.2
F	22	95500	134100	13.5	20.3	92000	131950	12.0	19.0
F	24	96000	136100	11.5	18.3	broke short	....	......	....
F	26	93690	136800	12.5	19.0	94200	133800	9.0	9.7
Average....		95086	135114	12.4	18.5	92323	130558	11.3	16.4
Gen.	Avg...	95026	135165	12.1	18.0	93260	125788	9.1	12.1

which had a longitudinal fissure with a transverse branch, showed good longitudinal ductility in both the outer part and the interior of the rail head. E rail number 24, which had some simple transverse fissures, showed good ductility in the outer part of the rail head section, but the longitudinal tensile specimen from the interior of the head broke "short" in testing, indicating low ductility, or perhaps a defect in the specimen. The results on these two rails correspond to previous experience; namely, that with simple transverse fissures, the ductility in the interior of the head is low, while with compound fissures the interior longitudinal ductility may be good. Unfortunately, however, we have no pictures of the original fractures in the track, and too few rails with fissures were found in the bending tests, to allow us from the results of this investigation, to correlate the tensile properties with the nature of the fissures.

For convenience of comparison, the average results for the several ingot positions are collected together in Table 6.

TABLE 6—AVERAGE ELONGATIONS

Rail Letter.	*O-Position.*	*M-Position.*
B	12.5	7.5
C	12.2	5.5
D	11.9	11.6
E	10.5	8.0
F	12.4	11.3
All	12.1	9.1

SUMMARY.

1. An investigation was made of a heat of rails on the Delaware, Lackawanna & Western Railroad, which was removed from service on account of four rails failing in track and showing transverse fissures after about two years in service. The rails were of the D. L. & W. 105 lb. section. Ninety-nine rails of this heat were gathered together at Scranton to be investigated, but unfortunately, through a misunderstanding, most of the rails had been taken for secondary track work before actual testing could be started, leaving 25 rails covered by this report.

2. From out of the middle of each rail, a 15 inch piece was cut by means of an oxygen-acetylene torch, for chemical analyses and tensile tests and the two long pieces were used for bending tests to disclose any fissures present in them.

3. Of the twenty-five rails, fissures were found in two of them. One F rail showed four fissures of the simple transverse type and a D rail showed one small fissure which was evidently the transverse part of a compound fissure, the main part of which was longitudinal and obliquely horizontal. We are unable to say what was the type of break of the rails broken in track, as photographs had not been taken and

the rails themselves were no longer at hand at the time of making this investigation.

4. Two samples were taken for analysis from near the middle of each rail, one from the O position near an upper corner of the head, and the other from the M position or interior of the head near the web. The average composition of the steel in the rails was found to be: carbon, .761; manganese, .83; phosphorus, .026; sulphur, .026; silicon, .170. In the O position, the carbon was about the same in the several ingot positions, but in the M position the carbon decreased downward of the ingot, that is, the steel became softer downward of the ingot.

5. Two specimens were cut for tensile tests from near the middle of each rail, one from the O position and the other from the M position. In the O position, the tensile strength and elongation were good in all the samples. In the M position or interior of the head, the steel showed good tensile properties in the rails from the lower part of the ingot, but there was considerable brittleness in the rails from the upper part of the ingot.

6. It had been hoped to determine the relationship between fissures and the tensile properties of the metal of the interior of the head, but a large part of the rails of the heat were not available for examination and of those examined only two showed fissures. The results on these two, however, correspond with previous experience, namely, that with simple transverse fissures the interior metal of the head is of low longitudinal ductility while with compound fissures, in which the transverse part is a branch that has grown off from a longitudinal fissure, the ductility in a longitudinal direction may be good.

Appendix G.

TESTS OF SPLICE BARS AT ALTOONA.

Pennsylvania Railroad.

This paper gives a report of tests of rail joint bars and rail joints made at the Altoona Laboratory of the Pennsylvania Railroad. The report was made May 8, 1915, by Mr. C. D. Young, then Engineer of Tests, to Mr. J. T. Wallis, General Superintendent of Motive Power, who has kindly permitted the Association to use the information. The text here given is essentially the report as made by Mr. Young, but the detail plottings of the laboratory results and some of the illustrations that accompanied the report have been omitted, to save space.

1. These tests of splice bars, covering the transverse strength under static and dynamic loading, were made in accordance with the verbal instructions which we received from the General Manager on January 4, 1915.

2. The object of the tests was to ascertain the relative stiffness of the standard joints under transverse load, and, where practicable, to increase this stiffness by changes in design or by heat-treatment.

DESCRIPTION AND COST.

3. Complete rail joints were made up for tests, using P. S. Section rail and the following types of splice bars, as shown in Table 1:

Table 1—Joints Tested.

Joints			
Four Hole—100 Lb. P. S. Rail		Six Hole—100 Lb. P. S. Rail	
No. 8 —Plain	Untreated	No. 8 —Plain	Untreated
No. 8* —Plain	Untreated	No. 8-A—100 Per Cent	Untreated
No. 8 —Plain	Heat Treated	No. 8 —Plain	Heat Treated
No. 8-A—100% M. W	Untreated	No. 8-B—Bonzano	Untreated
No. 8-B—Bonzano	Untreated	No. 8-C—Duquesne	Untreated
No. 8-B—Bonzano	Heat Treated		
No. 8-C—Duquesne	Untreated		
—Continuous	Untreated		
—Continuous	Heat Treated		
—Study No. 3	Heat Treated		
—Study No. 4	Heat Treated		
—Study No. 5	Heat Treated		
—Study No. 5-A	Heat Treated		
No. 8§ —Plain	Heat Treated		
No. 8§ —Plain	Untreated		
No. 12-B—Bonzano	Untreated		

*With Zollinger Tie Plate.
§Various lengths.

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4. In addition to the above, the following solid rails were also tested as basis for comparison of the joints:

100-lb. P. S. Section Rail—Untreated.
100-lb. P. S. Section Rail—Heat Treated.
125-lb. P. S. Section Rail—Untreated.
125-lb. P. S. Section Rail—Heat Treated.

5. Figures as to cost of the various splice bars were obtained from the Purchasing Department, as given in Table 2:

TABLE 2—PRICES

Kind of Splice Bars	Section	No. of Holes	Price Per Pair
Continuous	P. S.	4	$2.16
Bonzano, No. 8-B	P. S.	4	1.80
100 Per Cent, No. 8-A	P. S.	4	1.80
Duquesne, No. 8-C	P. S.	4	1.80
Plain, No. 8	P. S.	4	1.17
Plain, No. 8 (Heat Treated)*	P. S.	4	1.31
Bonzano, No. 8-B	P. S.	6	2.00
100 Per Cent, No. 8-A	P. S.	6	2.00
Duquesne, No. 8-C	P. S.	6	2.00
Plain, No. 8	P. S.	6	1.35
Plain, No. 8 (Heat Treated)*	P. S.	6	1.51
Combination 4 Tie-Tie-Plate, $1.50 per 100 Lb		§	1.64
Tie Plate, per pair			0.38

*Assumed cost of heat treatment per pound, $0.002.
§Zollinger Anti-Creeping Tie Plate.

METHOD OF TESTS.

6. The joints were put together by trackmen, using the maximum low temperature spacing of $\frac{5}{16}$ in. between the rail ends. Each joint was supported on the bed plate of the testing machine by two supports having surfaces curved to a radius of 5 in., spaced 20 in. apart, and the joints loaded in the center by means of a curved block, the loads being applied in increments, the deflection and set measured for each load, and the results plotted to determine the elastic limit.

7. In making the drop test the joints were assembled as before and mounted on square edge blocks set 20 in. apart inside edge to inside edge, and the rails struck in the center by a 2,200-pound tup having a curved striking face. The test was started with the first blow at one foot, second blow at two feet, and so on, the permanent set being measured at the center after each blow until it had reached or exceeded 1 in., then the blows were continued, one foot at a time, until some definite failure took place.

8. Two each of the joints in Table 1 were given a transverse test with head up, two each of the joints as indicated in Table 3 a similar test with head down, and two each of the joints in Table 9 a drop test with head up, and in addition transverse drop tests were made upon cer-

tain new splice bars having modifications in length and section as given in Table 3 and Table 8.

9. In order to make a comparison between the elastic limit of the various joints and of the solid rails, four pieces each of 100 pounds P. S. section and 125 pounds P. S. section rail were given a transverse test in both the original and heat-treated condition, on the same supports used for the joint tests, with head of rail up in all cases.

RESULTS.

10. These have been studied under the following general headings:

1—Comparison of Transverse Test with Head Up and Head Down.
2—Relative Efficiency of Different Joints.
3—Effect of Heat Treatment.
4—Strength of 100 and 125 Pound Rail.
5—Comparison of Efficiency of 4 and 6 Hole Joints.
6—Efficiency of Bars of Various Lengths.
7—Studies for Maximum Efficiency of a Plain and Anti-Creeping Type of Splice Bars.
8—Physical Properties of Bars and Rails Under Test.
9—Section Modulus and Stress at Transverse Elastic Limit.
10—Comparison of Dynamic and Static Tests.
11—Investigation of Joints Removed From Track.
12—Comparison of Weight and Cost to Efficiency.
13—Summary.

COMPARISON OF TRANSVERSE TEST WITH HEAD UP AND HEAD DOWN.

11. A portion of Table 3 gives a comparison of the various joints which we tested with head up and head down. It is seen that all of the bars, with the exception of the Plain No. 8, four-hole, Bonzano No. 8-B, six-hole, M. W. 100 Per Cent. No. 8-A, four-hole, and Duquesne No. 8-C, six-hole, are stronger with the head up than with the head down, although even in these exceptions the difference is very slight, the maximum being about 10,000 pounds.

12. We think the head down figures should not be used in judging the value of a splice, for the reason that the rail is not used this way in track, being subjected to the head down strains only when the wheel is approaching or leaving the joint, and then only when the support for the rail is insufficient and permits working of the rail, resulting in lever action within the splice. We have, therefore, in the following discussion eliminated the head down figures.

TABLE 3—RESULTS OF TESTS.

Type of Splice Bar	No. of Holes	T. D. Sheet No.	Elastic Limit of Joint		Ratio Elastic Limit of Joint / Elas. Limit of P. S. 100 lb. Rail		Test No.
			Rail Head Up	Rail Head Down	Rail Hd. Up	Rail Hd Dn.	
Plain No. 8.........	4	9675	50,000	60,000	29.0	34.0	1–4
Plain, No. 8.........	6	9676	70,000	60,000	40.0	34.0	5–8
Bonzano, No. 8-B...	6	9677	60,000	65,000	34.0	37.0	9–12
M. W. 100%, No. 8-A	6	9678	95,000	80,000	54.0	46.0	13–16
M. W. 100%, No. 8-A	4	9679	85,000	90,000	49.0	51.0	17–20
Continuous.........	4	9680	130,000	105,000	74.0	60.0	21–24
Duquesne, No. 8-C..	4	9681	110,000	90,000	63.0	51.0	25–28
Bonzano, No. 8-B...	4	9683	120,000	90,000	69.0	51.0	37–40
Bonzano, No. 12-B*.	4	9685	200,000	180,000	91.0	82.0	45–48
Plain, No. 8†.......	6	9688	125,000	95,000	71.0	54.0	55–58
Plain, No. 8†.......	4	9689	125,000	100,000	71.0	57.0	59–62
Plain, No. 8§.......	4	9686	65,000	....	37.0	....	49–50
Duquesne, No. 8-C..	6	9687	70,000	80,000	40.0	46.0	51–54
Continuous†........	4	9818	210,000	185,000	120–0	106–0	71–74
Bonzano, No. 8-B†..	4	9818	255,000	210,000	146.0	120.0	86–89
Study No. 3†.......	4	9906	255,000		146.0		104–105
Study No. 3†....... (Bars only)		9906	240,000		137.0		106
Study No. 4†.......	4	9907	180,000		103.0		107–108
Study No. 5†.......	4	9965	180,000		103.0		115–116
Study No. 5-A†.....	4	9965	180,000		103.0		117–118
100 Lb. Rail........		9814	175,000				63–64
125 Lb. Rail........		9814	220,000				67–68
100 Lb. Rail†.......		9814	260,000				65–66
125 Lb. Rail†.......		9814	375,000				69–70

*125 Lb. Rail.
†Heat Treated.
§Zollinger Tie Plate.
Elastic Limit of Untreated Rail taken as 175,000 Lb.–100 Lb. Rail.
Elastic Limit of Heat Treated Rail taken as 220,000 Lb.—125 Lb. Rail.

13. Plots of the transverse tests were used largely to determine the elastic limit of each joint, as this is, we believe, the best comparative data which we can offer for the relative efficiency of them. We have selected for the elastic limit the point on the curve where marked permanent set or deflection first takes place in the joint, and with this figure we have worked out their efficiency, namely, the ratio of the elastic limit of the splice to the solid rail in question.

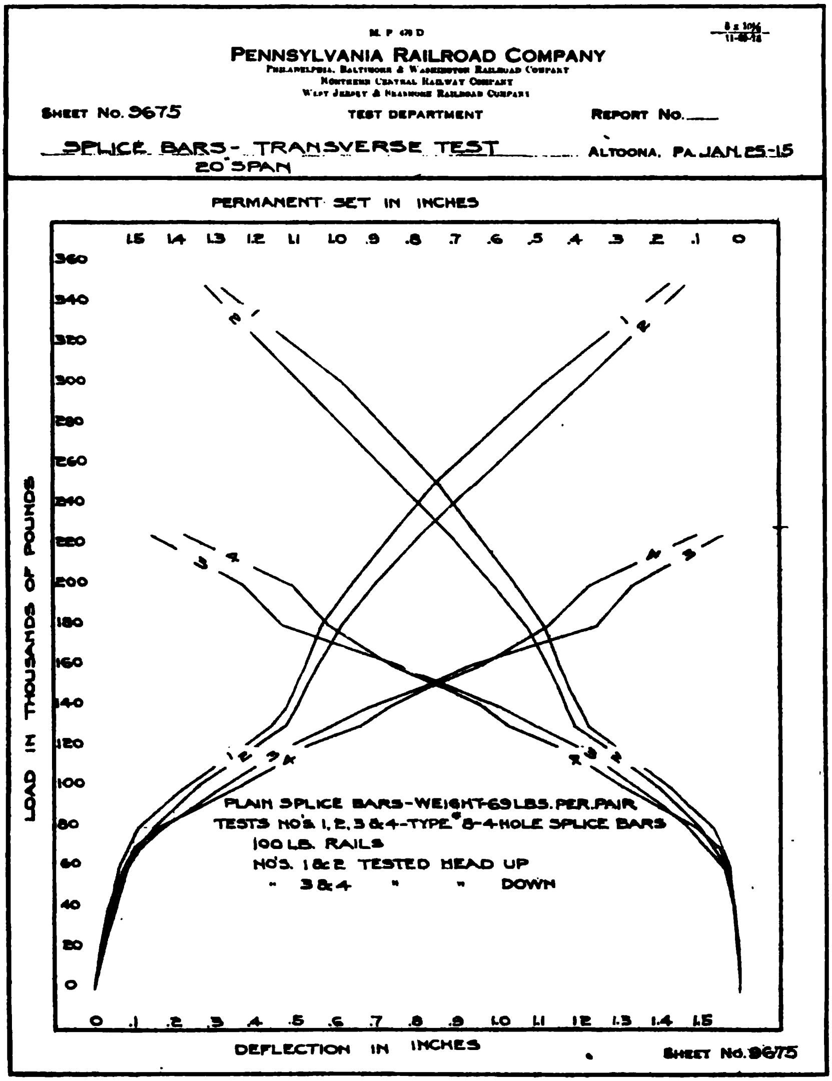


FIG. 1—SAMPLE DIAGRAM OF PLOTTED RESULTS.

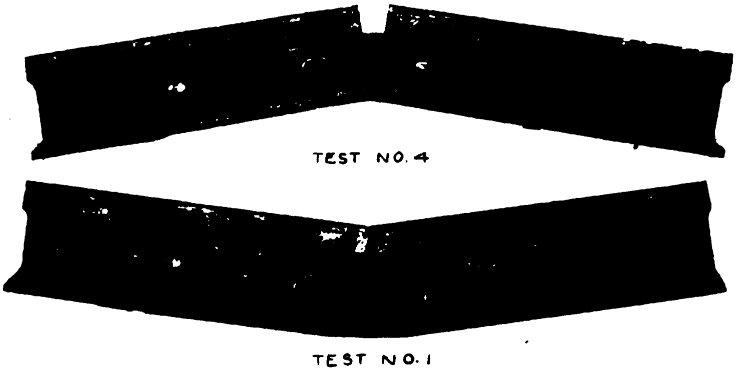


FIG. 2--PLAIN BAR NO. 8, FOUR HOLE.

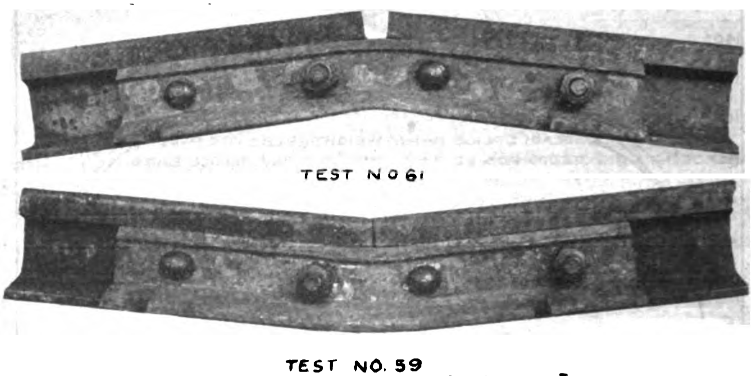


FIG. 3—PLAIN NO. 8, FOUR HOLE.

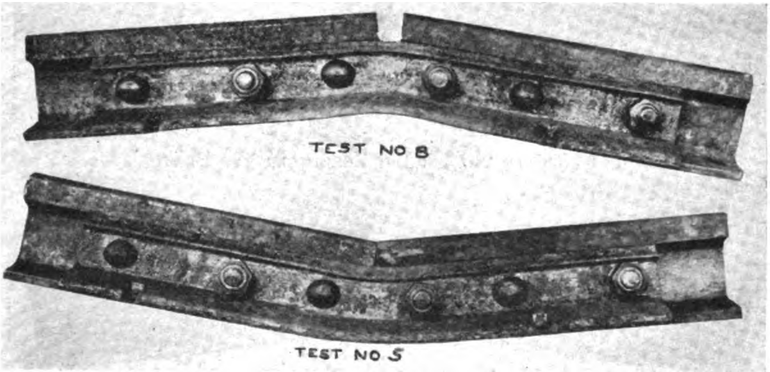


FIG. 4—PLAIN BAR NO. 8, SIX HOLE.

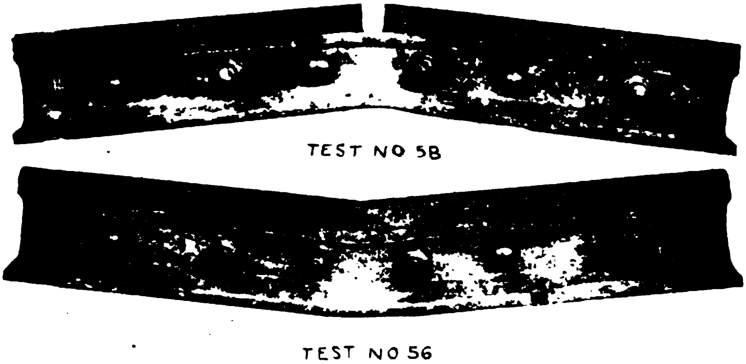


FIG. 5—PLAIN NO. 8, SIX HOLE.

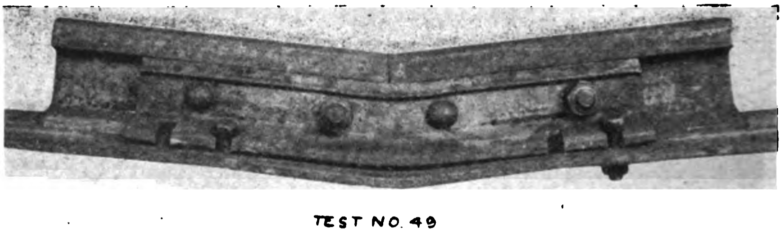


FIG. 6—PLAIN No. 8 WITH ZOLLINGER TIE PLATE.

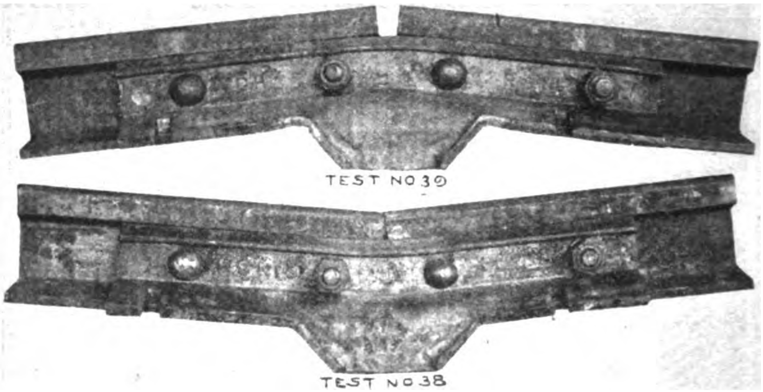


FIG. 7—BONZANO No. 8B, FOUR HOLE.

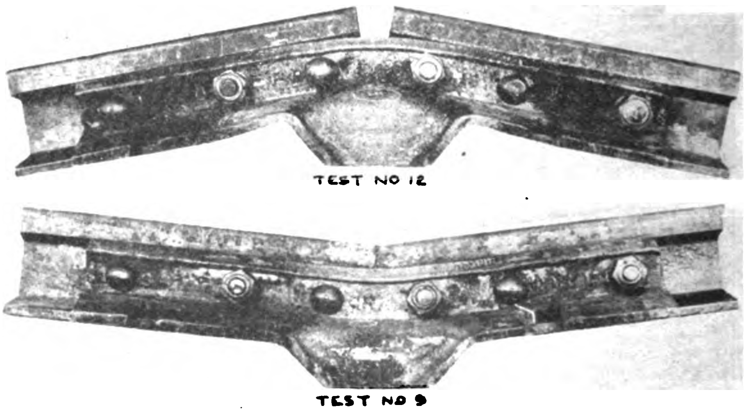


FIG. 8—BONZANO No. 8B, SIX HOLE.

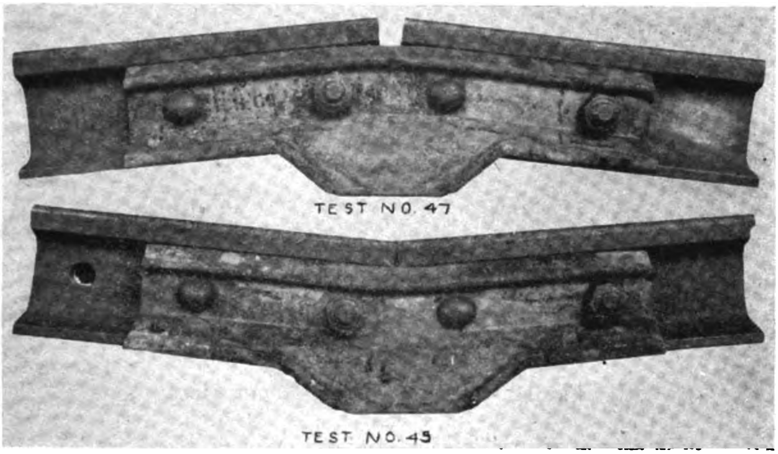


FIG. 9—BONZANO NO. 12B FOR 125-LB. RAIL, FOUR HOLE.

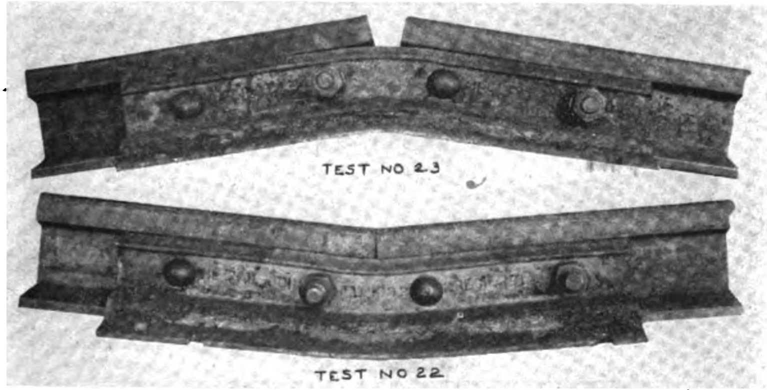


FIG. 10—CONTINUOUS, FOUR HOLE.

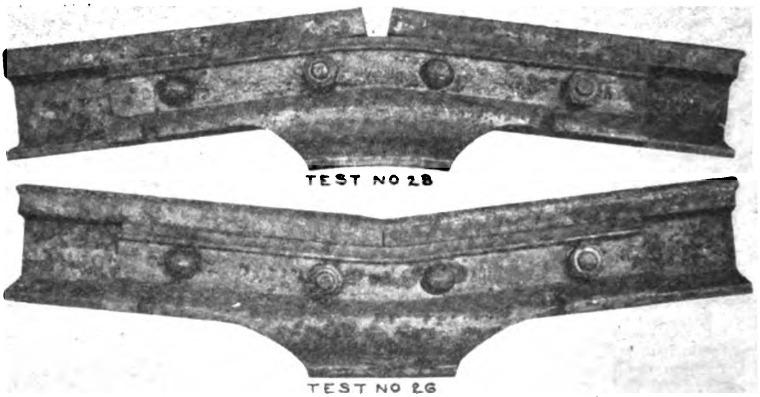


FIG. 11—DUQUESNE No 8C, FOUR HOLE.

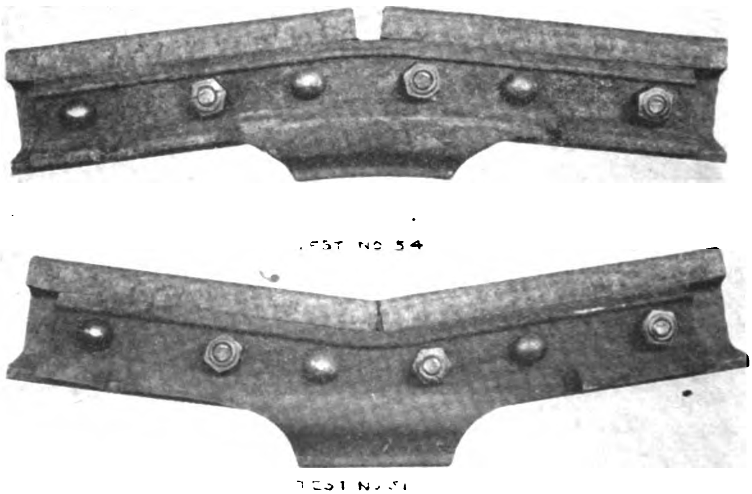


FIG. 12—DUQUESNE No. 8C, SIX HOLE.

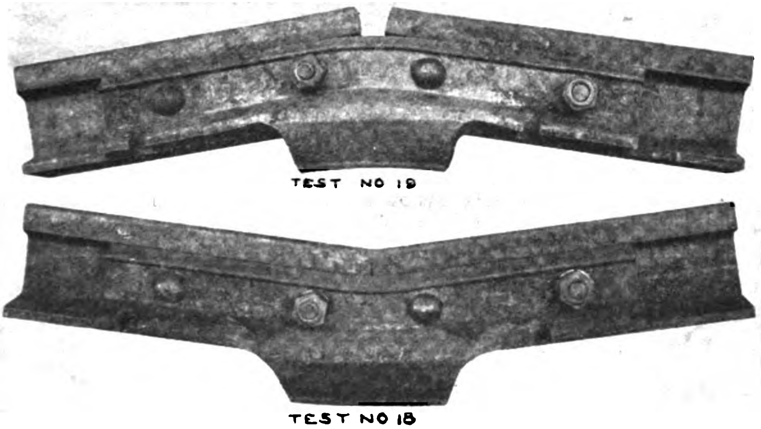


FIG. 13—M. W. 100 PER CENT., FOUR HOLE.

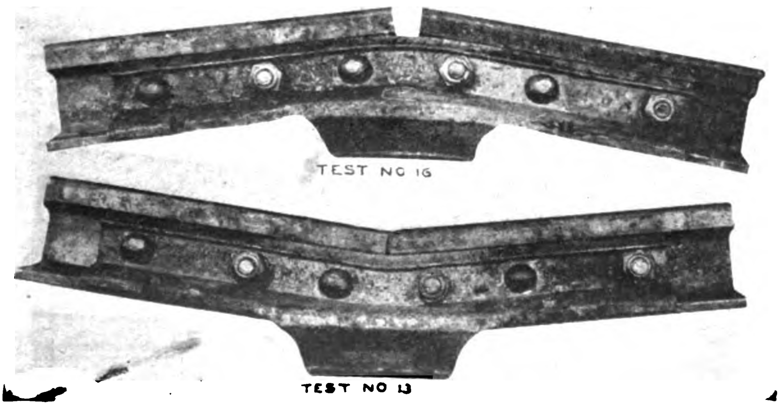


FIG. 14—M. W. 100 PER CENT. NO. 8A, SIX HOLE.

FIG. No. 15—STUDY No. 3, HEAT TREATED.

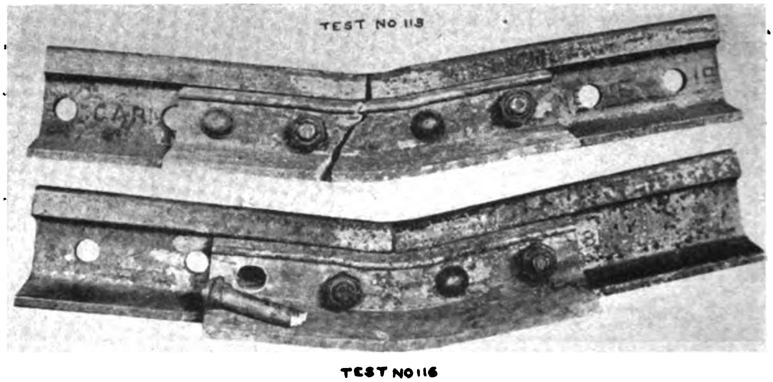


FIG. 16—STUDY No. 5, FOUR HOLE.

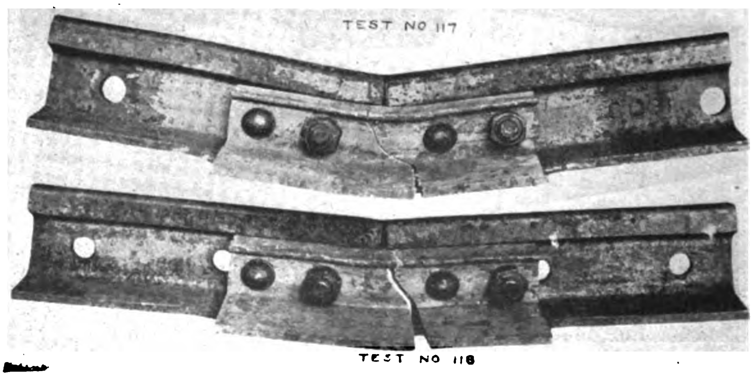


FIG. 17—STUDY No. 5A, FOUR HOLE.

14. Fig. 1 shows a sample diagram of the plotted results on cross-sectioned paper. Other diagrams were made to magnify the elastic limit which is shown in Table 3.

15. Illustrations of the bars after the transverse test are given in Figs. 2 to 17, inclusive.

RELATIVE EFFICIENCY OF DIFFERENT JOINTS.

16. With the enlarged and revised table, shown with Par. 12, it is seen that some slight modification in the "head up" values have occurred, as compared with our previous report, No. 15-9, dated January 26, 1915, slightly changing the efficiency of some of the joints at the elastic limit. This is due to the more careful study of the data which has now been made. By reference to Table 3 it will be seen, judging the efficiency of the joint by its elastic limit, as already described, and using the "head up" figures as a basis, places the 100-lb. rail joints, heat treated and untreated, in the order shown in Table 4.

TABLE 4—EFFICIENCIES.

Type of Joint	Treated	No. of Holes	Wt. per Pair, Lbs.	Efficiency Per cent
1—(Bonzano, No. 8-B*	Yes	4	75	146
(Study No. 3—30° Anti-Creeping Plate	Yes	4	109	146
2—Continuous	Yes	4	94	120
3 (Study No. 4	Yes	4	68	103
(Study No. 5	Yes	4	70	103
(Study No. 5-A	Yes	4	55	103
4—Continuous	No	4	94	74
5—Plain, No. 8	Yes	4 & 6	69 & 79	71
6—Bonzano, No. 8-B	No	4	75	69
7—Duquesne, No. 8-C	No	4	80	63
8—M. W. 100 Per Cent, No. 8-A	No	6	84	54
9—M. W. 100 Per Cent, No. 8-A	No	4	75	49
10—(Plain, No. 8	No	6	79	40
(Duquesne, No. 8-C	No	6	89	40
11—Plain, No. 8, with Zollinger Tie Plate	No	4	178	37
12—Bonzano, No. 8-B	No	6	76	34
13—Plain, No. 8	No	4	69	29

*Chrome nickel steel; therefore, is not on the same basis of comparison as the other plain carbon joints.

17. The beneficial effects of heat treatment are well portrayed here, in that the Bonzano and Continuous joints, when heat treated, are stronger at the elastic limit than the solid rail, whereas, in the untreated state, they are less than 75 per cent. of its strength. The Plain No. 8 bar, heat treated, compares favorably with the untreated Continuous and Bonzano joints of greater weight, and, as discussed later, Par. 31, it is shown that by increasing the section modulus of the Plain bar and heat treating, the efficiency is brought up to that of the rail itself; this is shown by Studies Nos. 4, 5 and 5-A.

18. It was found that 0.45 carbon Bonzano bars which were heat treated contained 0.32 per cent. chromium and 0.60 per cent. nickel, they probably having been made of Hayari steel. Due to the additional chemical hardeners in these bars, the efficiency developed is not fairly comparable with the rest of Table 4, and a bar of this hardness could harly be used, because the Brinell hardness is 267, which makes it about equal to the hardness of the rail. We have in all the other bars kept them softer than the rail, in order that they, instead of the rail, would wear when in service. Undoubtedly, the Bonzano bar treated to the proper hardness would show the same proportional increase in efficiency as obtained in the Continuous bar. This would then place the Bonzano bar, heat treated, between the Continuous and Studies Nos. 4, 5 and 5-A in Table 5.

19. It is, therefore, seen, that Study No. 3 makes the most efficient joint, and that Studies Nos. 4, 5 and 5-A, Plain bars, are equal to the stiffness of the rail itself, and 29 and 34 per cent. stiffer than the untreated Continuous and Bonzano bars, respectively, but, if it is desired to heat treat either the Continuous or Bonzano bars, they will be stiffer than the rail itself, but not as efficient as Study No. 3.

EFFECT OF HEAT TREATMENT.

TABLE 5—HEAT TREATMENT RESULTS.

Type of Rail or Splice Bar	Elastic Limit of Joint or Rail		Gain in Per cent.
	Before Treatment	After Treatment	
Solid Rail, 100-lb	175,000	280,000	60.0
*Solid Rail, 125-lb	220,000	375,000	70.0
Plain Bar, No. 8, Four-Hole	50,000	125,000	150.0
Plain Bar, No. 8, Six-Hole	70,000	125,000	79.0
Continuous Bar, Four-Hole	130,000	210,000	61.0
§Bonzano, Four-Hole	120,000	255,000	112.0

*High Carbon Steel.
§Chrome Nickel Steel.

20. Sections of 100 and 125 pound rails were heat treated, as well as splice bars of the Plain No. 8, four and six hole, and four-hole Continuous and Bonzano type. Table 5 shows the effect of the heat treatment upon the elastic limit under transverse strength, "head up." Both the rails and joints, after heat treatment, have had their stiffness materially increased. This increase in stiffness, in heat treatment, amounts to from 60 to 150 per cent. of the untreated bars at their elastic limits. It would, therefore, seem that in order to produce a splice bar which will increase the efficiency of the joint, that one of the simplest and most economical ways is to heat treat the material. This treatment consists in heating the material above the recalescence point (approximately 1500 degrees Fah.) and quenching in water from that temperature, and then annealing the hardened steel at a temperature of approximately 1050

degrees Fah. This process of heat treatment should not add more than approximately $5.00 per ton to the cost of the steel, and, as shown, will increase the stiffness of the bar certainly not less than 50 per cent. and still have the bar softer than the rail. The large increase which is shown in the case of the Plain No. 8 four-hole bar is due to the relative softness of the material of the untreated bar. This resulted in a very considerable increase in the stiffness when the bar was treated.

21. Certainly, from these results, the value of heat treatment of splice bars cannot be disregarded, and a heat treatment requirement should be incorporated in the specifications covering the future purchase of splice bar material.

STRENGTH OF 100 AND 125 POUND RAILS.

22. In Table 5, showing the effect of heat treatment, it will be noted that the increase in the load at the elastic limit of the 125-pound over the 100-pound rail is 26 per cent. for the untreated materials and 34 per cent. for the heat-treated materials. As the section moduli, both above and below the neutral axis for the 125-pound rail, is 46 per cent. greater than for the 100-pound rail, it is of interest to observe that, considering their section moduli, the expected gain has not been made in the strength of the 125-pound over that of the 100-pound rail. This is shown in Table 6:

TABLE 6—TESTS OF RAILS.

	Rail		Increase in Strength 125-lb. Rail Over 100-lb. Rail
	100-lb.	125-lb.	
Transverse Load at Elastic Limit, Untreated, Lbs.....	175,000	220,000	26.0%
Transverse Load at Elastic Limit, Heat Treated, Lbs...	280,000	375,000	34.0%
Section Modulus above Neutral Axis B. Q'............	13.71	20.00	46.0%
Section Modulus below Neutral Axis, B. Q'............	15.91	23.30	46.0%

23. We are unable to account for this apparent loss in strength in the 125-pound rail, as with the higher carbon content which exists in this rail, even greater strength should be shown over the 100-pound rail than that which the section modulus figures would indicate. It shows that we are not getting the increased strength in the 125-pound beam which we have a right to expect, from the increase in the rail section, and that, perhaps, the 125-pound rails are not receiving as much work in rolling as the 100-pound rails. This may be due to the fact that rolls of the same power are being used for the rolling of both sections, or that the cooling rate is not the same. Furthermore, it may not be correct to make a comparison of strength with the section modulus figures where the rail head and base are not identical in form, or have proportional radii at the junctures of the head and base to the web.

COMPARISON OF FOUR AND SIX HOLE JOINTS.

24. From Table 7, showing the efficiency of the joints of the four and six hole type, there appears to be nothing gained, so far as strength in transverse loading is concerned, by using a six-hole instead of a four-hole joint. If anything, the four-hole joint seems to have a slightly higher efficiency than those of the six-hole type. It should be noted, however, that in two cases this is not true and in two others there is no difference.

TABLE 7—FOUR HOLES AND SIX HOLES COMPARED.

	Efficiency of Joint—Per cent.				Gain Per cent. Over Six-Hole	
	Four-Hole		Six-Hole			
	Head Up	Head Down	Head Up	Head Down	Head Up	Head Down
Plain, No. 8—Heat Treated..........	71	57	71	54	0	3
Bonzano, No. 8-B—Untreated........	69	51	34	37	35	14
100 Per cent. No. 8-A—Untreated......	49	51	54	46	—5	5
Plain, No. 8—Untreated...........	29	34	40	34	—11	0

25. The slight difference shown for the joints is probably due to the fact that in order to increase the length of splice and make the bars of the same weight for the six as for the four hole, a decrease has been made in the section, thus offsetting whatever slight advantage this longer joint might otherwise have. As these tests were made on a 20-in. span, it can hardly be said that they portray all of the advantage which might come from a six-hole joint, as the span is too short for this length of bar, but the span selected represents fairly the tie spacing; it would seem that a four-hole joint for 100-pound rail is sufficient, providing it is made of proper section and material. It has the advantage of fewer bolts to install and maintain, and greater cross sectional area for the same weight.

EFFICIENCY OF BARS OF VARIOUS LENGTHS.

26. In order to determine what should be the minimum length of a four-hole bar of constant weight which could be developed to provide the maximum sectional area, experiments were conducted with untreated and heat-treated bars of 18½, 23¼ and 26½-in. length, the present standard, but in all cases the No. 8 section was used. In the case of the 23¼-in. length and 18½-in. length, the same spacing of bolts was used between the center bolts as is the practice in the standard four-hole bar (5½-in.) and between the center bolts and the outside bolts the same spacing as is used in the six-hole bars (4½-in.).

27. The results of these tests are shown in Table 8 and indicate

that no loss in efficiency is to be expected from the reduction of the length of the splice bar to 18½-in., either when tested on 20-in. supports or 26-in. supports, which latter spacing probably represents the maximum for the joint in track. Of course, the saving in weight, of the same section, is directly proportional to the reduction in length, and, due to the reduction of the length of the splice, certain studies were made of new designs of splice bars of heavier section, keeping in mind the advantage which might be obtained from weight reduction, due to increase in length.

TABLE 8—LENGTHS COMPARED.

Type	Heat Treated	No. of Holes	Length Inches	Distance Between Supports Inches	Elastic Limit Head Up	Efficiency of Rail Joint Per cent.	Sheet No.
No. 8 Plain.	No.	4	26½	20	50,000	29.0	9675
No. 8 Plain.	No.	4	26½	20	45,000	26.0	9816
No. 8 Plain.	No.	4	26½	26	60,000	34.0	9817
No. 8 Plain.	Yes	4	26½	26	125,000	71.0	9620
No. 8 Plain.	No	4	23¼	20	40,000	23.0	9816
No. 8 Plain.	No	4	18½	20	55,000	31.0	9816
No. 8 Plain.	No	4	18½	26	50,000	29.0	9817
No. 8 Plain.	Yes	4	18½	26	125,000	71.0	9620
No. 8 Plain.	No	4	18½	20	120,000*	69.0	9963 & 9964

*Joint eccentric to load.

STUDIES FOR MAXIMUM EFFICIENCY OF A PLAIN AND ANTI-CREEPING TYPE OF SPLICE BAR.

28. To develop a splice bar which would be comparable with the present Plain No. 8 bar and used in combination with an anti-creeping tie plate, a number of studies were made which resulted finally in a design shown in Fig. 18, as Study No. 3.

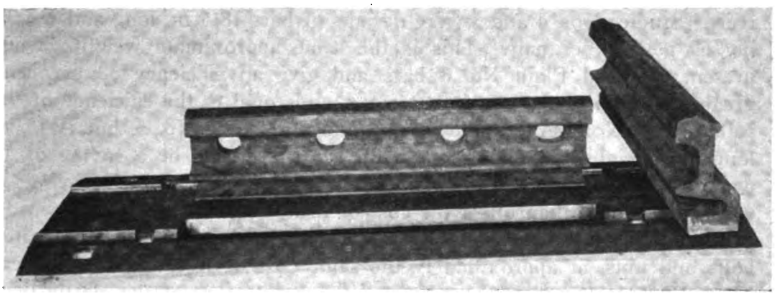


FIG. 18—STUDY No. 3.

This design consists in the Continuous two or four tie tie-plate, slotted out to receive a splice of the base support type, but not having the side extending flange, similar to the Continuous. In applying a splice bar of this character to the track, it will

be necessary to bolt the splice to the rail and then introduce the splice into the slots of the tie plates.

29. When heat treated and tested, this bar gave the maximum efficiency of any tested, namely, 146.0 per cent. The bar is devoid of spike slots and that part under the base of the rail is engaged by the tie plate and acts in conjunction with it for anti-creeping.

30. One other feature to be noted in the construction is that with the tight fitting of the base portion of the bar into the plate, loose bolts in the rail joint will not permit the tie bar to separate itself from the rail and when the bolts become loose it will probably afford some additional support to the joint such as is not to be found in any other design. A pair of these bars, 18 in. in length, the length of bars tested and as shown in Table No. 8, weigh 63 pounds, as compared with 69 pounds for the Plain No. 8 bars, 26½ in. in length, and 94 pounds for the Continuous. Subsequent tests with a 15-in. four-hole bar, Study No. 5-A, proved so satisfactory that we have added on sheet No. 9904 a 15-in. bar of this design, identified as Study No. 3-A, a pair of which weigh 52 pounds. Thus a saving in weight of 17 pounds can be obtained with Study No. 3-A bar over the present Plain No. 8 bar and 41 pounds over the Continuous. Where anti-creeping is demanded in connection with the joint, this bar can be used, both for attachment to two ties and to four ties, this tie plate being comparable with the Continuous and other bars which have spike slots in the base for fastening to two ties. A plate 30 in. in length and weighing 49 pounds can be used for two ties and for four ties a plate 70 in. in length and weighing 133 pounds can be used.

31. Making use of the information derived from these tests, Studies Nos. 4, 5 and 5-A were prepared. These bars were heat treated (see Table 3) and gave an efficiency of 103 per cent., which is 29 and 34 per cent. in excess of the untreated Continuous and Bonzano bars, respectively. Studies Nos. 4 and 5 were designs of bars 18½ in. long and weighing 69 pounds per pair. This is the same approximate weight as our present standard Plain No. 8 bars and give an efficiency 32 per cent. greater than this same bar, heat treated, and equal to the efficiency of the rail. Study No. 5-A has the same section as Study No. 5, but is 15 in. long and weighs 55 pounds, and with it there would be a saving of 14 pounds over the present standard No. 8 Plain bar, which saving in weight will more than offset the cost of heat treatment. In other words, Study No. 5-A bar can be furnished, heat treated, and with heat-treated bolts and nuts, at approximately the same cost or less than our present No. 8 Plain bar, untreated, and give a strength figure at the elastic limit equal to the rail and three times greater than the Plain No. 8 bar, untreated. These special bars (Studies Nos. 4, 5 and 5-A) have a disadvantage, in that they do not have as good a holding feature between the tie and the rail for spiking as the present Plain bar and probably could not be used with success, where this is an important feature. They have, however, the advantage of a much higher strength for the same cost and could be used on track where the prevention of creeping is not demanded,

in which case Study No. 3 or 3-A could be used. Study No. 5-A would require a special tie plate, as indicated on the drawing, in order to keep the track in gauge at the joint. However, there would be no reason for spacing of ties at joints with this efficiency of bars.

PHYSICAL PROPERTIES OF BARS AND RAILS TESTED

32. Table 8A gives the physical properties of all bars tested, both heat treated and untreated. The hardness was found by observation along the bar and the other values by a 2-in. test specimen cut from the bar.

33. This information indicates that in the treatment of a bar, in order to insure that it will be softer than the rail, the Brinell hardness

TABLE 8A—PHYSICAL PROPERTIES OF SPLICE BARS AND RAILS.

Type	Number Holes	Heat Treated	Load per Sq. In. at		Elong. % in 2"	Reduc. of Area %	Brinell Hardness	Test Number
			Elastic Limit	Ultimate				
Plain—No. 8	4	No	32,800	77,960	25.5	41.31	155	1 to 4.
Plain—No. 8	6	No	......	......	......	......	150	5 to 8.
Bonzano—No. 8-B	6	No	......	......	......	......	135	9 to 12.
M.W.100%—No. 8-A	6	No	......	......	......	......	153	13 to 16.
M.W.100%—No. 8-A	4	No	39,370	82,450	24.5	43.50	168	17 to 20.
Continuous	4	No	39,376	79,698	28.0	51.18	163	21 to 24.
Duquesne—No. 8-C	4	No	39,870	81,650	26.5	45.92	158	25 to 28.
Bonzano—No. 8-B	4	No	48,018	95,760	21.0	38.93	184	37 to 40.
Bonzano—No. 12-B	4	......	......	......	......	......	168	45 to 48.
Plain (with Zollinger Tie Plate) No. 8	4	No	......	......	......	......	157	49 to 50.
Duquesne—No. 8-C	6	No	......	......	......	......	147	51 to 54.
Plain—No. 8	6	Yes	......	......	......	......	202	55 to 58.
Plain—No. 8	4	Yes	58,500	94,460	25.5	50.20	211	59 to 62.
Rail—100 Lb	......	......	66,545	133,050	10.0	13.83	256	63 to 64.
Rail—100 Lb	......	Yes	112,350	177,075	12.5	35.35	326	65 to 66.
Rail—125 Lb	......	......	69,245	134,950	9.0	10.49	260	67 to 68.
Rail—125 Lb	......	Yes	115,700	182,050	11.7	28.63	361	69 to 70.
Continuous	4	Yes	64,108	103,455	22.6	52.99	218	71 to 74.
Plain—Special Length (20" Span) No. 8	4	......	......	......	......	......	......	75 to 80.
Plain—No. 8 (26" Span)	4	......	50,570	99,675	20.5	42.27	193	61 to 84.
Study No. 2	4	Yes	64,640	95,905	24.5	56.36	207	85 to 92.
Study No. 2	......	......	......	......	......	......	177	85 to 90.
Study No. 2—Tie Plates	......	Yes	......	......	......	......	212	91 to 92.
Bonzano—No. 8-B	......	Yes	84,448	126,556	19.5	53.21	267	86 to 89.
Study No. 3	4	Yes	69,450	108,800	20.0	41.20	188	104 to 105.
Study No. 4	4	Yes	71,200	112,250	21.5	50.12	229	107 to 108.

should not exceed 250, and it will be noted that the treatment given the bars in no case produced a hardness greater than this, except the Bonzano No. 8B, which, when treated, gave a hardness of 267. This figure is the average we would expect in an untreated rail. The Bonzano bars were treated in a manner entirely similar to the others, but due to the difference in the chemical composition which was unknown at the time of the treatment, the elastic limit and the ultimate strength increased beyond that which was intended at the time of treatment, and for this reason,

as noted in Par. 18, the Bonzano heat-treated bar gave a very high figure, equalling Study No. 3.

34. The tentative specifications which have been drawn up and sent you with our letter of February 17, 1915, covering heat-treated splice bars, would have rejected this bar on account of high ultimate strength, it being 11,000 pounds higher than the upper limit. The results on sheet No. 9845 indicate that the elastic limit of the untreated bars, such as we are receiving, is considerably lower than what we require in the proposed specifications. This is due to the requirement of a high elastic limit produced by treatment whch we propose, in order to produce the desired stiffness.

SECTION MODULUS AND STRESS AT TRANSVERSE ELASTIC LIMIT.

35. In Table 8B is shown the relative efficiency of the bars, section modulus, moment of inertia, area and weight of two bars. From

TABLE 8B—EFFICIENCY, SECTION MODULUS AND MOMENT OF INERTIA—FOUR-HOLE BARS—100-LB. RAILS.

Type	Per cent. Efficiency 2-Bars	Section Modulus 2-Bars		Moment Inertia	Area Sq. In.	Weight 2-Bars
		Above N. A.	Below N. A.			
Continuous—4 Hole	79	9.26	15.26	27.14	12.92	93.8
Bonzano—No. 8-B	74	11.73	9.45	33.32	12.28	74.5
Duquesne—No. 8-C	69	13.45	11.78	41.34	13.50	80.0
M. W. 100%—No. 8-A	57	13.56	11.50	40.98	13.18	75.5
Plain—No. 8	34	5.78	7.04	13.06	9.66	69.0
Plain—M. W. 16344-A	50	7.28	7.72	15.06	10.17	68.34
100 Lb. Rail	....	13.71	15.91	41.9	9.97	....
125 Lb. Rail	....	20.00	23.30	70.0	12.5	....
125 Lb. Bonzano—No. 12-B	96	19.52	15.22	61.26	16.86	109.0
125 Lb. Plain—No. 12	....	12.10	13.42	32.06	14.78	109.0
Study No. 3 (30 Inch Plate)	146	*11.4	*19.3	*35.84	17.6	109.0
Study No. 4	103	9.10	13.58	22.48	13.48	68.0
Study No. 5	103	9.19	12.5	21.64	13.5	70.0
Study No. 5-A	103	9.19	12.5	21.64	13.5	55.0

*Assumed.

this data, Fig. 19 has been plotted with the section modulus as abscissa and the stress in pounds at the elastic limit as ordinate. The points have been plotted for the section modulus both below and above the neutral axis. Although there is some irregularity in the plotted figures, due probably to the distribution of the material in the section and some irregularities in the material itself, the data indicates that straight lines of proportionality may be drawn for the untreated and heat-treated materials which will give a fair indication of what may be expected in transverse load at the elastic limit for any given section modulus above or below the neutral axis.

36. With the curves on Fig. 19, and knowing the section modulus of any bar, a very fair idea can be obtained of the strength to be ex-

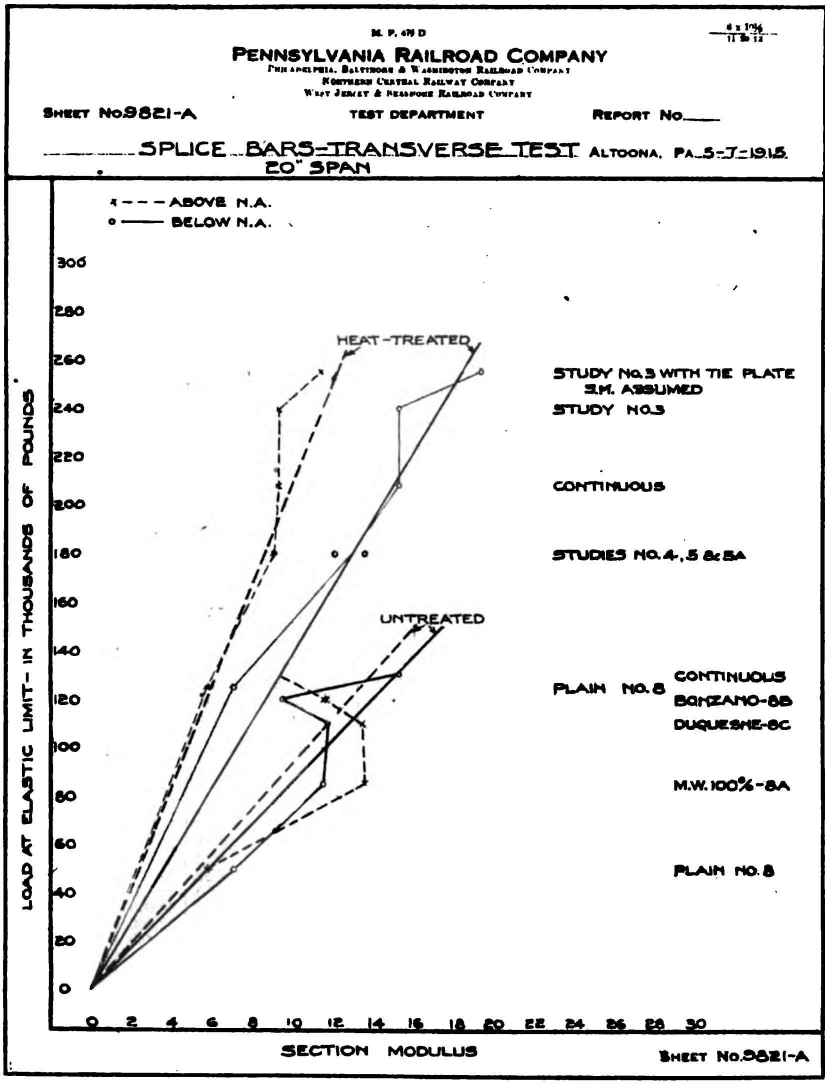


FIG. 19—ELASTIC LIMIT AS RELATED TO SECTION MODULUS.

pected when the bar is tested "head up," or, having established the strength desired in a pair of bars, one may ascertain approximately, and within the chemistry of the steel tested, what section modulus will be required with treated or untreated material.

COMPARISON OF DYNAMIC AND STATIC TESTS.

37. All of the four-hole 100-pound bars and 100-pound rails, untreated, were subjected to the drop test as explained under Par. 7, and in addition the Plain No. 8 bar, heat treated, and bars representing Studies Nos. 3 and 4, were also subjected to the same test.

38. These results indicate that the stiffness under shock, of bars representing Studies Nos. 3 and 4, both heat treated, when compared with the untreated rail, was greater than the stiffness of the Plain No. 8 bar, heat treated, and the Plain No. 8 bar with the Zollinger tie plate, while this stiffness was not so evident in the static test. It seems, from these results, as though the raising of the elastic limit by heat treating the material has benefited the bar, under shock, to a greater extent than under static loading.

39. We have endeavored to make a comparison of the static and dynamic strength of the joints, but this does not seem to be possible, probably due to the fact that the joints under the drop test, being assembled structures, are subject more to variations than under the slow application of the static load in the test machine. Table 9 has been prepared, however, and is of interest in bringing out the relative differences that appear between the static and the dynamic test.

TABLE 9—DYNAMIC AND STATIC TESTS.

TYPE NO.	One Pair of Splice Bars				E. L. Bars / E. L. Rail*	Transverse Elastic Limit of Bars	Base Unit Stress at E.L.%♯	E. L. Found from 2-In. Test Piece	Dynamic Moment of Resistance $\frac{1+Ax^2}{y}$
	Wt. Lbs.	Area Sq. In.	Section Modulus Head	Section Modulus Base					
1	2	3	4	5	6	7	8	9	10
No. 8 Plain, H. T....	69.0	9.66	5.78	7.04	71.0	125,000	88791	58,500	43.27
Continuous.........	93.8	12.92	9.26	15.25	74.0	130,000	42696	39,376	68.15
No. 8-C, Duquesne..	80.0	13.51	13.45	11.78	63.0	110,000	46689	39,870	61.63
No. 8-A, 100% M.W.	75.5	13.18	13.56	11.50	49.0	85,000	36956	39,370	59.27
No. 8-B, Bonzano...	74.5	12.27	11.73	9.45	69.0	120,000	63492	48,013	53.0
No. 8, Plain........	69.0	9.66	5.78	7.04	29.0	50,000	35511	32,800	43.27
Study No. 3......... (30-In. Plate)	109.0	17.6	§11.40	§19.30	146.0	255,000	65000	69,450	§71.62
Study No. 4........	68.0	13.5	9.10	13.59	103.0	180,000	64400	71,200	66.05

*Elastic Limit load of P. S. 100 Lb. rail, 175,000 Lb.
♯Based upon elastic limit load found on transverse test.
§Assumed.

40. We now compare the difference between the unit fibre stress at elastic limit for the static transverse load and that which was actually found in the tensile test of the two-inch specimen as taken from the information on sheet No. 9895 [not shown]. In order to establish this unit fibre stress at the elastic limit, the section modulus of the base has been taken in each case, as the base is that portion which is under tensile stress. In column 10 is shown the moment of resistance of each of the sections of

the bars based upon an arbitrary axis, within the tup and two inches above the top of the rail. Using figures in this column, Table 10 has been prepared, showing the moment of resistance of the bars of different types and the stress in foot pounds which caused a set of 0.1 inch, and this in turn has been compared with the static load of the bars at the elastic limit.

TABLE 10—TESTS COMPARED.

TYPE NO.	Moment of Resistance	Foot Pounds at 0.1 In. Set	Static Load at Elastic Limit
Rail, 100 Lb.	38.5	9962	175,000
Continuous	68.2	3368	130,000
No. 8-C, Duquesne	61.6	3050	110,000
No. 8-A, 100% M. W.	59.3	2492	85,000
No. 8-B, Bonzano	53.0	2846	120,000
No. 8, Plain	43.3	1600	50,000
Study No. 3, H. T.	72.3	11480	255,000
Study No. 4, H. T.	66.05		180,000
No. 8, Plain, H. T.	43.3	3880	125,000

41. The results have been grouped to keep the treated and untreated materials separate. The bars rank in the same relative order as their ability to absorb kinetic energy as might be predicted from their moment of resistance, and the same relative order applies when comparing the elastic limit of the bars under static test, with the exception of the No. 8-B Bonzano bar. In this case, however, it is to be noted that the elastic limit of the material in the untreated Bonzano bar, which contained chromium and nickel (see Sheet No. 9845), was higher than was found in the other bars tested transversely, and this, together with the fact that the Bonzano bar under the drop test did not have these elements, may and probably does account for the relatively better showing of the Bonzano bar, section modulus considered, under static than under drop test.

42. The most striking result found in the drop test is the ability of the solid rail to absorb dynamic shock, as compared with the built up structures, for it is noted that the rail which has a calculated moment of resistance lower than the lowest joint has a tested moment of resistance six times greater. We feel that this indicates rather clearly that in the solid bar the moment of resistance should never be compared with the moment of resistance of built up structures, and it seems questionable, therefore, whether built up structures under dynamic test will give results which are fairly comparable with what should be expected from the solid rail. Such conditions as tightness of bolts, the friction at the fishing surfaces, the exact location of the striking face of the tup and the inability of the built up structure to react under the shock, appear greatly to influence the results so as to make the drop test of questionable value, although in this test, as has been pointed out (Par. 41), the calculated moment of resistance of each of the built up structures does follow very closely the ability of the joints themselves to absorb dynamic force.

INVESTIGATION OF JOINTS RECEIVED FROM TRACK.

43. An examination at the scrap pile in Altoona was made of the condition of 960 bars removed from track. These were sorted into five general groups of characteristic failures, as shown in Figs. 20 and 21.

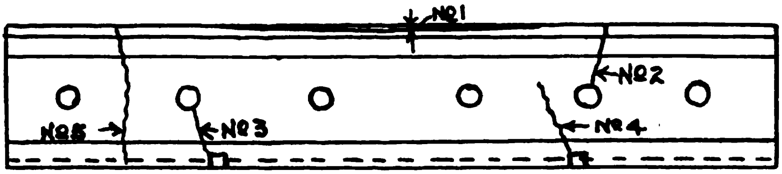


FIG. 20—DIAGRAM OF TYPES OF BREAKS.

1—Splice bars removed from the track due to being abraded on the top fishing surface (No. 1), the depth of wear varying from $\frac{1}{32}$ to $\frac{1}{16}$ in., and having a maximum wear from the end of the rail of approximately 8 in. It was also noted on the longer six-hole bars that similar wear occurs at the ends of the splice bars. This is not so much in evidence on the shorter bars, being confined to the top of the center. Of the 960 bars examined, 24 per cent. were of this class. All of these bars could, in our opinion, be reclaimed by reforming.

2—Cracked from the top of the bar down into a hole (No. 2).

3—Cracked, in a great majority of the cases, through the spike slot and entering the hole (No. 3).

4—Cracked, starting from the bottom and generally from the spike slot and not entering the hole (No. 4).

5—Broken bar and from all appearances has broken from the bottom up, generally starting from the spike slot (No. 5).

Note.—The pictures of the depending flange have no reference to the character of break, as similar breaks were found in Plain bars.

44. It is seen from the tabulation shown on Fig. 22 that the class 5 break was the predominating fracture. We hardly feel that the examination has covered a sufficient number of the different designs of bars to draw any conclusions so far, regarding the design and its breakage; furthermore, no information as to the mileage which has run over each of the joints is available.

45. Class 5 failure amounted to 60 per cent. of all of the bars broken, or 44 per cent. of the total examined, including class 1. Classes 3 and 4 may be viewed together, these constituting 35 per cent. of the cracked bars, or 27 per cent. of the total examined. A great majority of these cracks originated at the spike slot, although in the depending flange type of joint there were a large number which started at a point where the depending flange leaves the bottom horizontal line. But 6 per cent. of the total

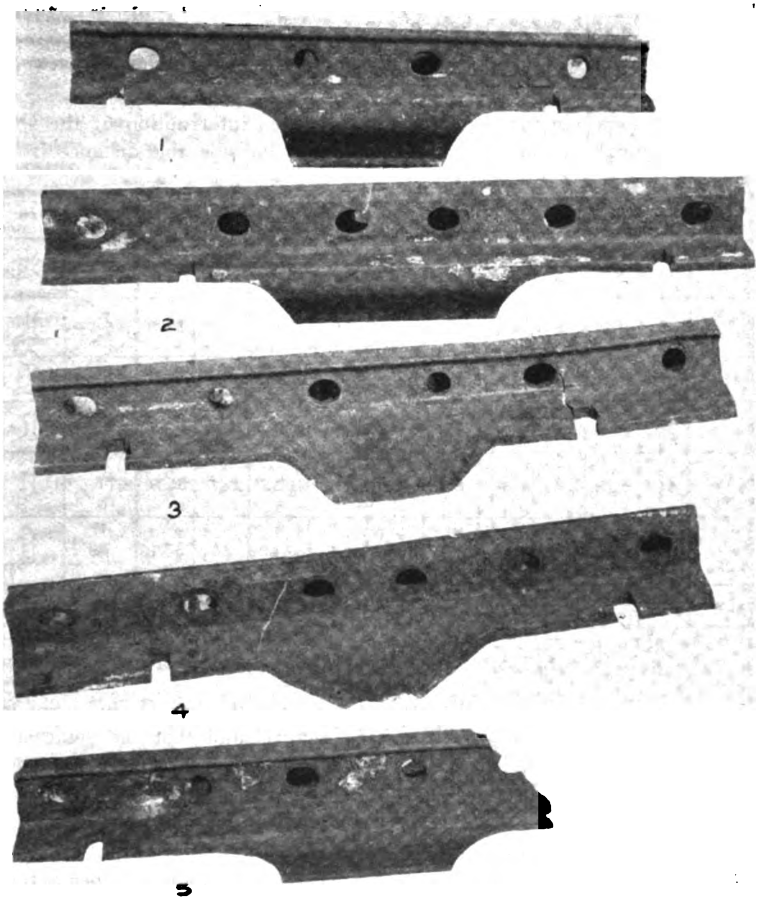


FIG. 21—CHARACTERISTIC FAILURES IN TRACK.

cracked and broken bars, or 4.5 per cent. of the total bars examined, showed cracks from the upper edge of the bole hole.

46. We feel that a general conclusion can be drawn from this limited examination as follows:

1—That approximately one-fourth of the bars which are removed from the track can be reclaimed by reforming, although this percentage would probably increase if a reforming plant were in operation and a closer limit were placed on the amount of wear permitted between the rail and the splice bar.

2—The spike slot in the bar, due to the sudden interruption of the section, although this interruption occurs some considerable distance from the end of the rail, localizes the strain upon the bar at this point to such an extent as to readily cause fracture, and that the spike slot of the angle bar should be, if it is possible, removed to avoid interruption of the section. (See Studies Nos. 3, 3-A, 4, 5 and 5-A, Pars. 28 to 31.)

Name of Splice	No. 1 Worn on Top		No. 2 Cracked Top to Hole		No. 3 Cracked Bottom to Hole		No. 4 Cracked in Metal at Any Place		No. 5 Broken at Any Place		Totals	Sketch of Section
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent		
P.R.R. No 8 A&C 100% Duquesne	13	17.57	6	8.	7	9.46	6	8.	42	56.76	74	
P.R.R. No 8-B Bonzano	5	9.25	8	14.8	9	16.6	13	24.	19	35.19	54	
P.R.R. No 8 Plain	122	50.	25	10.25	11	4.51	17	6.96	69	28.28	244	
P.S. No 8 Plain	33	100.	0		0		0		0		33	
P.S. No 8 A&C Duquesne	46	9.64	4	.84	83	17.4	78	16.35	266	55.76	477	
P.S. No 8-B Bonzano	14	18.	0		28	35.9	6	7.69	30	38.46	78	
Totals	233	24.27	43	4.48	138	14.38	120	12.5	426	44.38	960	of 5 classes
			43	6.	138	19.	120	16.5	426	58.6	727	of classes 2-3-4 & 5

FIG. 22—TABULATION OF BREAKS IN TRACK.

3—The tendency in future design of angle bars should be to obtain a greater section modulus below the neutral axis than has heretofore appeared to be desirable, as 94 per cent. of the broken bars examined had cracks originating in this location.

COMPARISON OF WEIGHT AND COST TO EFFICIENCY.

47. As so little difference was found in the strength for the four and six hole joint, and as we were not able to obtain the Continuous splice of the six-hole type, the discussion which follows has been based upon the efficiency of joint for the four-hole splice only.

48. There is tabulated in Table 11 the different types of joints with the efficiency, weight of two bars, ratio of the efficiency to the weight, and the price complete of the joint with the tie plate.

TABLE 11—WEIGHTS AND COST.

Type of Bar	Heat Treated	Efficiency Per cent.	Weight 2-Bars Lbs.	% Ratio Efficiency / Weight	Price—Dollars 2-Bars	2-Tie Plates	Total
Continuous	No	74.0	93.8	79.0	2.16	......	2.16
Bonzano, No. 8-B	No	69.0	74.5	93.0	1.80	0.38	2.18
Duquesne, No. 8-C	No	63.0	80.0	79.0	1.80	0.38	2.18
M. W. 100%, No. 8-A	No	49.0	75.5	65.0	1.80	0.38	2.18
Plain, No. 8	No	29.0	69.0	42.0	1.17	0.38	1.55
Study No. 3-A (30" Plate)*	Yes	146.0	102.0	143.0	1.11§	0.95	2.06
Bonzano, No. 8-B‡	Yes	146.0	74.5	196.0	1.95§	0.38	2.33
Continuous	Yes	120.0	93.8	128.0	2.35§	......	2.35
Study No. 5-A	Yes	103.0	55.0	188.0	1.06§	0.38	1.44
Plain, No. 8	Yes	71.0	69.0	103.0	1.31§	0.38	1.69
Study No. 3-A (30" Plate)*	Yes	146.0	185.5	79.0	1.11§	2.20	3.31
Zollinger Tie Plate and No. 8, Plain*	Yes	71.0	215.0	33.0	1.31§	2.20	3.54
Zollinger Tie Plate and No. 8, Plain*	No	37.0	178.0	21.0	1.17	1.64	2.81

*Zollinger tie plate tested was ⅝" thick and 9⅝" wide, whereas Study No. 3-A plate was heavier, being ¾" thick and 10¾" wide.
§Cost of heat treatment estimated at $5.00 per ton.
‡Chrome nickel steel—all other bears medium carbon steel.

49. In the above Table 11 the cost of the track tie plate was added to the cost of the bars and, therefore, the cost represents the total cost of the joint, including two tie plates for each of the joints in question. Exceptions to this are the Plain No. 6 joint with the Zollinger tie plate, Study No. 3-A, with the 70-in. plate, and Hollinger tie plate of same thickness as No. 3-A plate and No. 8 Plain bar, heat treated. We do not feel that it is fair to include the cost or efficiency of these joints in the comparison for the reason that the cost covers a tie plate for four ties rather than two, and has anti-creeping features in combination with four ties, and also, in the case of the Zollinger design, the proper efficiency comes into play only after the spikes and the slots of the plate and bars are in actual contact. In this comparison of the four-hole joints of the different types, it is only proper to keep separate the joints which have anti-creeping features from the others.

50. If efficiency, as determined by this method of laboratory testing, will be borne out in service, the review of the figures for the various bars, heat treated and untreated, will express what is commercially the best which can be obtained for the service. In the untreated bars in the first group, Table 11, it is seen that the Continuous bar has the highest efficiency and costs $2.16. This bar, when compared with the Plain No. 8 bar, heat treated, in the second group, at $1.69 with tie plate, is not as good a proposition as regards cost, although the efficiency is slightly bet-

ter, and it would seem that if an efficiency of joint, as now obtained from our best splice bars is all that is desired, the heat treated Plain No. 8 bar would be satisfactory.

51. If further improvement in the joints is desired, a resort to heat treatment seems to be the best method available, considering both strength and cost. A study of the second group of bars, all of which were heat treated, indicates that the best results were obtained from bars, Study No. 3-A, with 30-in. plate, and the Bonzano, No. 8-B bars, as already mentioned; however, the Bonzano joint was heat treated to a greater hardness than the rail and, therefore, its efficiency for equal treatment would probably be slightly less than that of the Continuous bars. The Bonzano and Continuous bars, heat treated, are the highest in price. They have an efficiency greater than bars, Study No. 5-A, which equal the efficiency of the rail, and the Plain No. 8 bars, but they are not as high as bars, Study No. 3-A, with the 30-in. anti-creeping plate. For $2.06, as compared with $2.35, a bar of higher efficiency than either the Bonzano or Continuous can be obtained. This gives a two-tie joint with anti-creeping features, the same as the Continuous or Bonzano bars. Study No. 5-A bars, with an efficiency equal to that of the rail, can be purchased at a lower price, namely, $1.44, than the Plain No. 8 bars, which cost $1.69. Therefore, for a joint which shall be as strong as the rail and have anti-creeping features, Study No. 3-A bars may be used and when anti-creeping features are not desired, Study No. 5-A bars can be used. In the third group in Table 11, which shows the design incorporating the feature of tying four ties together to provide for anti-creeping, is shown the cost and efficiency of Study No. 3-A, Zollinger tie plate of the same thickness as the plate used in Study No. 3-A, with the Plain No. 8 heat-treated bars, and the Zollinger tie plate without the Plain No. 8 bars, untreated. Here again it is shown that Study No. 3-A bars can be purchased for slightly less money than the same plate with the Plain No. 8 heat-treated bars, the cost being $3.31, as compared with $3.51. The present design of Zollinger tie plate with heat-treated Plain No. 8 bars can be purchased for $2.81. These bars, however, have a very much lower efficiency than Study No. 3-A bars with the 70-in. plate, being only one-fourth as strong. Where the anti-creeping feature and the tying of four ties together is essential, it would seem, therefore, that Study No. 3-A bars are well worthy of consideration.

52. An outline of specifications for heat-treated medium carbon and alloy steel track bolts is appended, and included in this appendix are photographs of various designs of tie plates and joints which bear directly upon this investigation and which will no doubt be of interest as illustrating what existed in the art prior to the present patent time limitation. The sources of these photographs are shown at the bottom of each of the sheets.

[The specifications and illustrations referred to in this paragraph are not reproduced in the present paper.]

53. If any heat-treated bars are to be used, they should be purchased under specfications and inspection which will insure that the treatment has produced in the bar the properties which are essential, in order to produce results equal to those found in these tests.

SUMMARY.

54. As indicated in our previous report, No. 15-9, under date of January 26, 1915, this investigation required a more thorough study in the laboratory than had been made at that time. The joints tested should be followed up in service trials, in order to determine if the laboratory results are borne out in service.

55. It has been found that by heat treating the Plain No. 8 bars, and at a very much lower cost, it has an efficiency almost equal to the Continuous and slightly better than the Bonzano bars, untreated. Therefore, if the present efficiency of the Continuous and Bonzano joints is satisfactory, by heat treating our Plain No. 8 bars results comparable with these joints can be obtained at a lower cost.

56. If a joint equal in efficiency to the rail itself is desired, this can be obtained by heat treating the Continuous or Bonzano joints, but at a much lower cost a design of Plain bar (see Studies Nos. 4, 5 and 5-A) can be used which will give the efficiency of the rail.

57. The Plain bar, heat treated (Study No. 5-A), shows a strength, at the elastic limit, equal to that of the rail itself, and can be purchased at a price lower than our present No. 8 Plain bars, which have a strength of about one-third of the rail (see Par. 31 and 50). If this bar is placed in the track it should be used with heat-treated bolts only, as, being shorter, it may require greater strength of bolt than the present No. 8 Plain bars. It has the objectionable feature of requiring a different drilling for the outside bolt holes in the splice bar and a special tie plate if it is necessary to spike the rail to the tie at the joint. The spiking of the rail at the joint, however, only comes at those places where the joint happens to be over a tie, as this design does not carry with it the necessity of tie spacing, due to the joint being equal to the strength of the rail. Where it is necessary to prevent rail creeping at the joint, Study No. 3-A bars may be used, thus obtaining the highest efficiency, and at a cost lower than for other joints of this type.

Appendix H.

QUICK BEND TEST FOR RAIL.

By W. C. CUSHING, for Sub-Committee on Quick Bend Test.

W. C. CUSHING, *Chairman;*
G. M. DAVIDSON,
J. R. ONDERDONK,
F. S. STEVENS,
F. M. WARING,
M. H. WICKHORST,
Sub-Committee.

In this communication I propose to furnish a brief description of the quick bend machine and a statement of the final results reached by Mr. Waring from the mass of data taken by the Altoona Laboratory with the quick bend test machine of the Pennsylvania Railroad in comparison with the regular drop test work when inspecting rails for the Pennsylvania Railroad System. These results are, of course, preliminary and subject to modification from time to time in the light of additional data.

This cannot be considered as a report of conclusions of the Sub-Committee, but can be considered as a report of information furnished by the Sub-Committee for inclusion in the general report of the Rail Committee.

DESCRIPTION OF MACHINE.

Quick Bend Test Machine.

The machine consists of a hydraulic press and intensifier, the design and operation of which were made to conform to specifications outlined under the supervision of Mr. J. T. Wallis, General Superintendent, Motive Power, Lines East of Pittsburgh, Pennsylvania Railroad.

Press.

The press is of the four-column inverted type having a clear distance of 3′ 4″ x 12″ between columns. The main ram, 16″ diameter x 12″ stroke, is cast solid with the moving platen, which is guided on the four columns. The twin pull back rams, 6 inches in diameter, are symmetrically located at the sides of the main ram, and are connected with the moving platen by 1¾-inch rods. The over-all dimensions of the press are 5′ 6″ x 3′ 1″ base x 8′ 11½″ height. The maximum clearance between the moving

Rail Report 76, December, 1918.

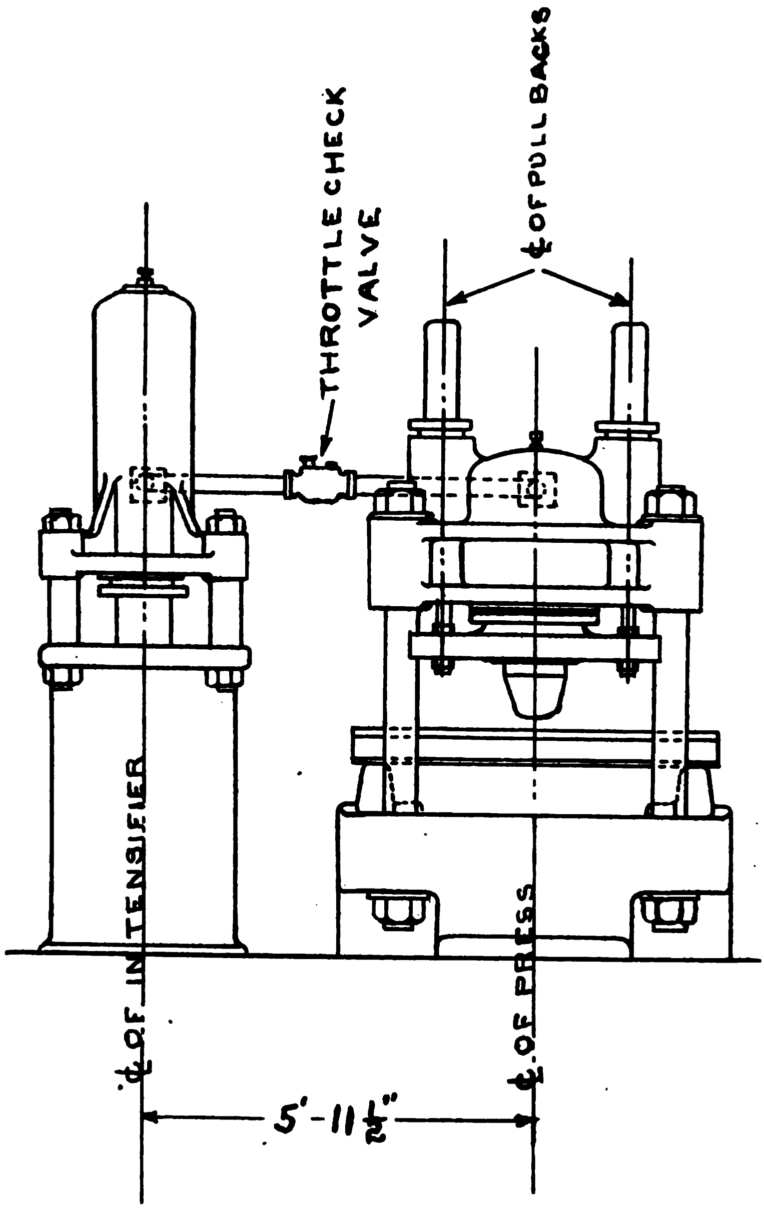


FIG. 1—GENERAL ARRANGEMENT OF QUICK BEND TEST MACHINE.

platen and base of the press is 2′ 2″. The total weight complete with the loading head and two supports is approximately 22,000 lbs. (See Fig. 1.)

Intensifier.

The over-all dimensions of the intensifier are 2′ 11″ x 2′ 11″ base x 9′ 6½″ height, and is of the single pressure type with a total weight of approximately 11,000 lbs. The ram which extends from the high-pressure

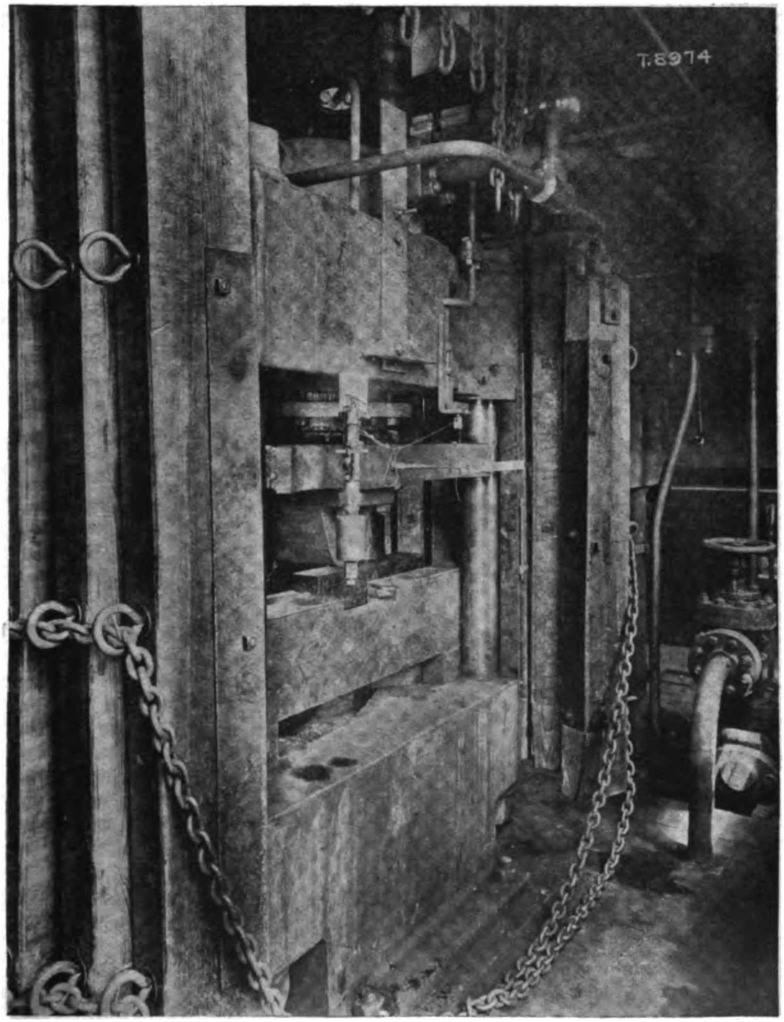


FIG. 2—QUICK BEND TEST MACHINE SHOWING SAFETY GUARDS.

cylinder to the base-pressure cylinder is integral with the base-pressure piston, and has a total stroke of 36 inches. The diameters of the ram and base-pressure piston are, respectively, 9 inches and 26 inches, which give a step-up ratio of about 8.35 to 1. The high-pressure intensifier cylinder is directly connected with the press-ram cylinder through a 2-inch extra heavy pipe provided with a 2-inch check and stop valve.

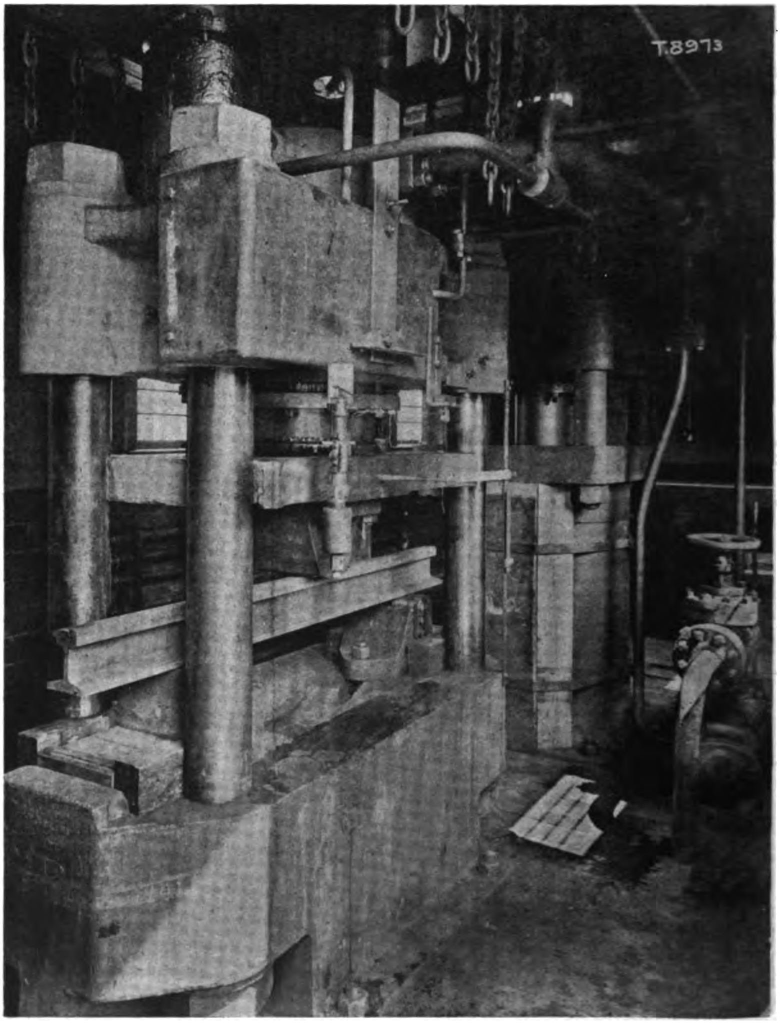


FIG. 3—QUICK BEND TEST MACHINE SHOWING RAIL IN POSITION FOR TEST.

Operation.

The operation of the machine is controlled by a bronze three-way valve, having balanced exhaust. By admitting 450 lbs. per square inch line pressure to the base cylinder of the intensifier, the pressure in the high-pressure cylinder thereof, and, consequently, in the ram cylinder of the

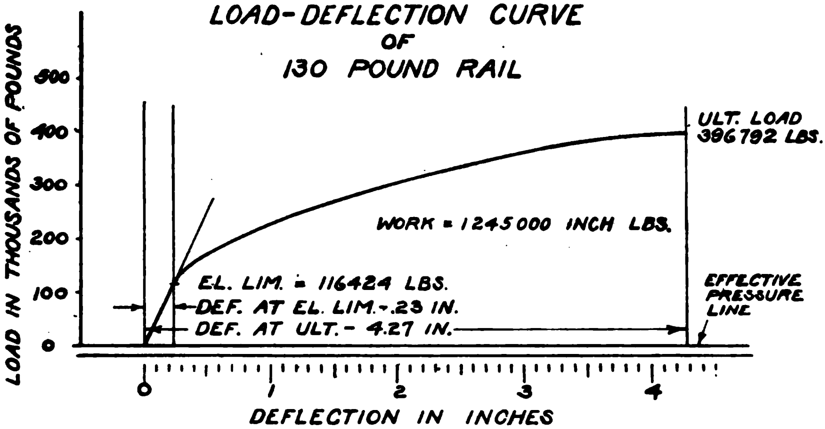


Fig. 4—Indicator Card Reproduced Showing Calculations.

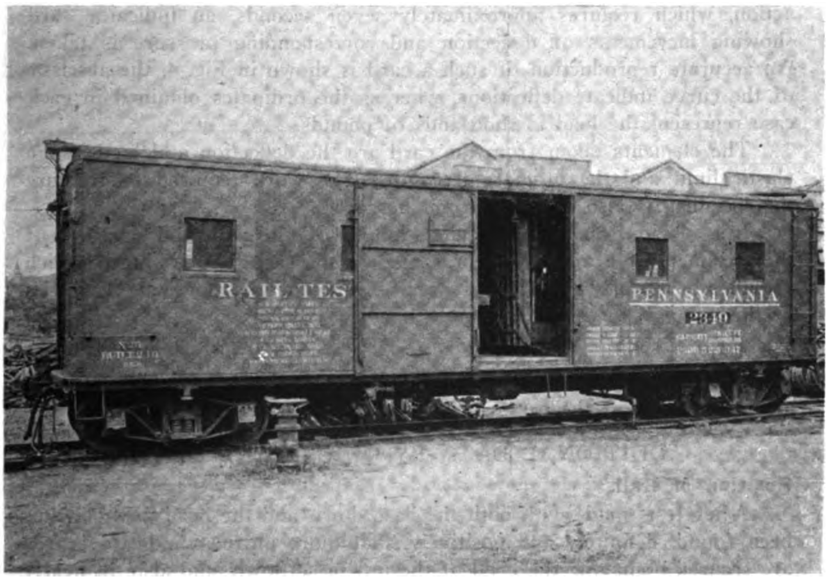


Fig. 5—View of Car in Which Quick Bend Test Machine is Housed.

press, is raised to approximately 3,760 lbs. per square inch, developing a total capacity in the press of about 756,000 lbs. (378 tons). The 36-inch stroke of the intensifier ram actuates the entire 12-inch travel of the main ram by intensified pressure alone, thus assuring a smooth, continuous curve on the indicator card.

The machine was accurately calibrated in order to ascertain its actual effective working pressure.

The machine is so designed that no more than 60 per cent. of its total capacity is necessary for the maximum test requirements in order to prevent all undue strain and wear on the parts.

Safety guards are arranged around the machine, as shown in Fig. 2, to prevent the broken pieces from flying when the rail specimens rupture under tests.

Indicating Apparatus.

A hydraulic indicator is used for registering the pressure required for a relative deflection of the specimen, the indicator being in direct communication through a ½-inch pipe with the main ram chamber, the movement of the indicator drum being actuated by the stroke of the main ram. A general arrangement of the indicating apparatus is shown in Fig. 3.

The rail test specimen, properly marked, is placed on the supports of the press and pressure is applied, through the leading head on the ram, at the center of the rail until rupture of the specimen occurs. During this action, which requires approximately seven seconds, an indicator card showing increments of deflection and corresponding pressure is taken. An accurate reproduction of such a card is shown in Fig. 4, the abscissæ of the curve indicate deflections, whereas the ordinates obtained in each case represent the load in thousands of pounds.

The elements taken from the card are the deflection and load at the elastic limit and the ultimate strength. The work required to fracture the specimen is also obtained from the card.

It is obvious that the complete ranges of elasticity and ductility of the specimen are graphically represented on the card thus produced, which provides a means of making a precise study of the physical properties of the material in the rail.

The Car.

The machine is installed in a modified class X-25 car. Fig. 5 shows an outside view of the car, which is equipped for passenger train service.

ADDITIONAL DATA BY QUICK BEND TEST.

Position of Rail.

After tests made with both the base down and the head down, it has been found, definitely and positively, that more uniform indicator cards are secured by having the head of the test piece down, and also, in nearly every case, a straight fracture at the center was obtained, whereas in the head-up tests it was frequently found that the rail would break into three

or more pieces; a head-down fracture being illustrated in Fig. 6, fracture No. 1, while a head-up fracture is illustrated by No. 2 of the same figure.

Elastic Limit.

The elastic limit of a rail is undoubtedly of primary importance in the determination of its wearing qualities and stiffness. In order to study the elastic properties of the rails a series of tests was conducted on increasing spans with the load applied at the center, to ascertain what effect the length of span had on the elastic limit load of the rail. The tests were conducted on four rails, two from one ingot, and two from

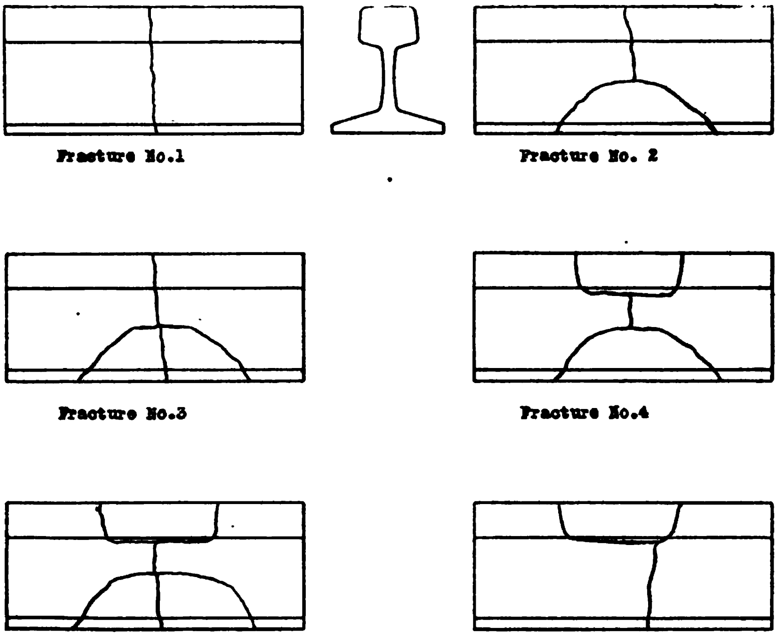


FIG. 6—TYPES OF FRACTURES IN QUICK BEND TEST.

another. Eight specimens were cut from each of the two rails taken from the same ingot, the one set being tested with the base down, whereas the other set was tested with the head down, and the elastic limit loads obtained on the increasing spans are plotted in Fig. 7 for the rails rolled from one ingot. One sheet only is furnished, as it is considered typical for the rest. The dotted lines represent the mean curve through the respective plotted points, while the full line indicates the theoretical curve, which was determined as follows:

The unit stress was determined for each point along the curve, that is,

$$\frac{\text{Elastic limit load} \times \text{Span}}{4} \div \text{Section Modulus} = \text{Unit Stress in extreme fiber.}$$

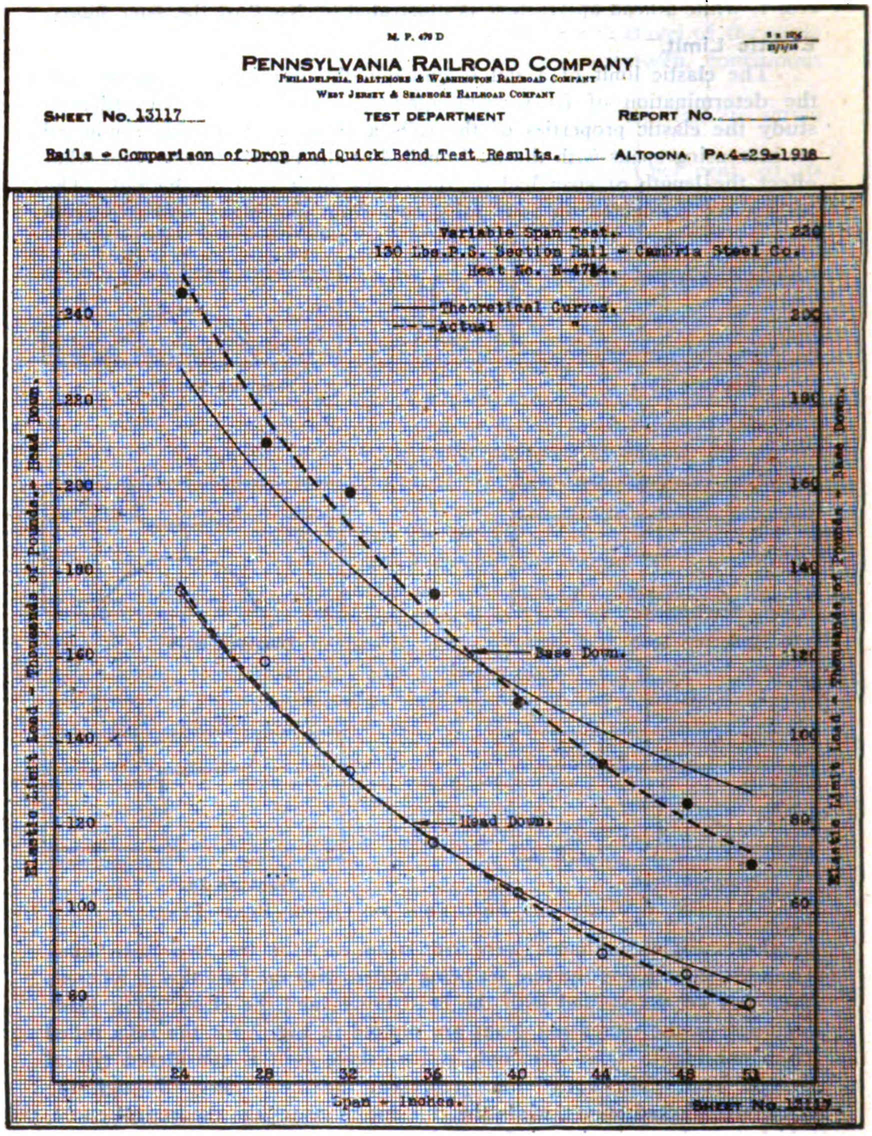


FIG. 7—ELASTIC LIMIT AS RELATED TO SPAN OF SUPPORTS.

These stresses were determined from the test results, then averaged and the average stress was then employed in determining what loads would be required on the respective spans in order to produce the calculated average stress; in other words, the theoretical elastic limit load

$$P = \frac{4 \times \text{Section Modulus} \times \text{Average Unit Stress}}{\text{Span}}$$

It will be noted in Fig. 7 that the curve for the head-down tests follows the respective theoretical curves much closer than does the curve for the base-down tests. The curve further indicates that with the same homogeneous steel (free from segregation and other defects) in all the test specimens we would expect approximately the same unit stress in the extreme fiber at the elastic limit load, irrespective of the span; in other words, for a given span there would be a commensurable elastic limit load, and the curve would be hyperbolic.

It will also be noted that in the base-down curve the theoretical curve falls below the mean curve of tests at the smaller spans, and at the larger spans it is higher than the mean curve of tests. These deviations of the mean curve from the theoretical curve may be due to the fact that on the shorter spans the vertical shear stresses are high and there is less of a bending action than on the longer spans.

Elongation.

It has been generally considered that the elongation of a material under stress is a direct measure of its ductility. The mean curves obtained by plotting the results of elongations against the corresponding deflections at ultimate loads of the quick bend test results obtained from the rails of each mill are illustrated by Fig. 8. The relation which exists between these two characteristics is direct. It will be noted that the curves on all sheets have approximately the same slope. We would, therefore, expect that for a given elongation of the material in the rail there would be a corresponding deflection. It follows, then, *that the deflection at the ultimate load, as well as the elongation, is an indication of the ductility of the material.*

Work Done in Fracturing Specimens.

The mean curves resulting from plotting the results of work done in fracturing the specimens against the corresponding deflection at ultimate load for all tests of the first, middle and last rollings of each mill, are illustrated in Fig. 9. It will be observed that the deflection is in a general way a function of the work done in fracturing the rail specimens. As the work done in fracturing the specimens very likely is an indication of the capacity of the rail to resist shock, it is probable that the deflection of the rail at ultimate load is also, to a more or less degree, a measure of this property of the rail.

Elastic Limit Load and Deflection at Ultimate.

Since it is apparently desirable to secure a certain minimum elastic limit load, together with a certain amount of ductility, which is desired

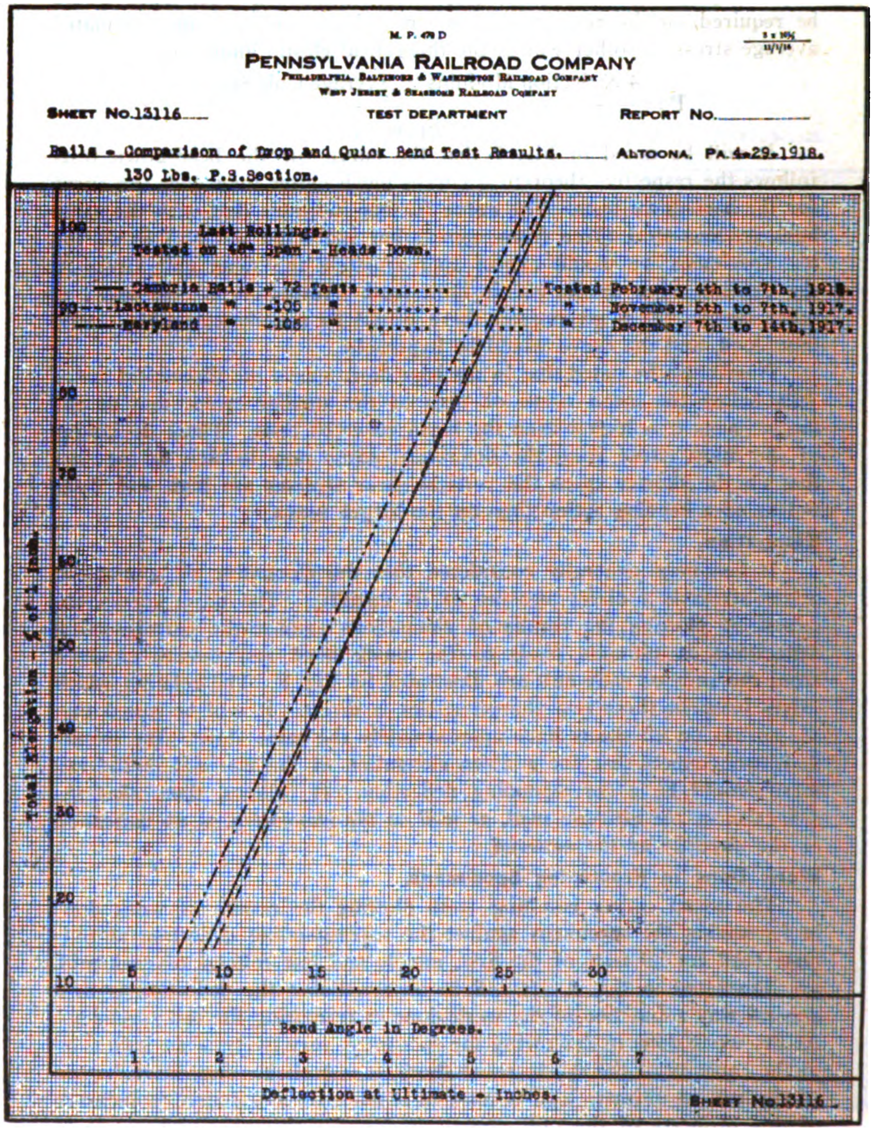


FIG. 8—DEFLECTION OF RAIL AS RELATED TO ELONGATION.

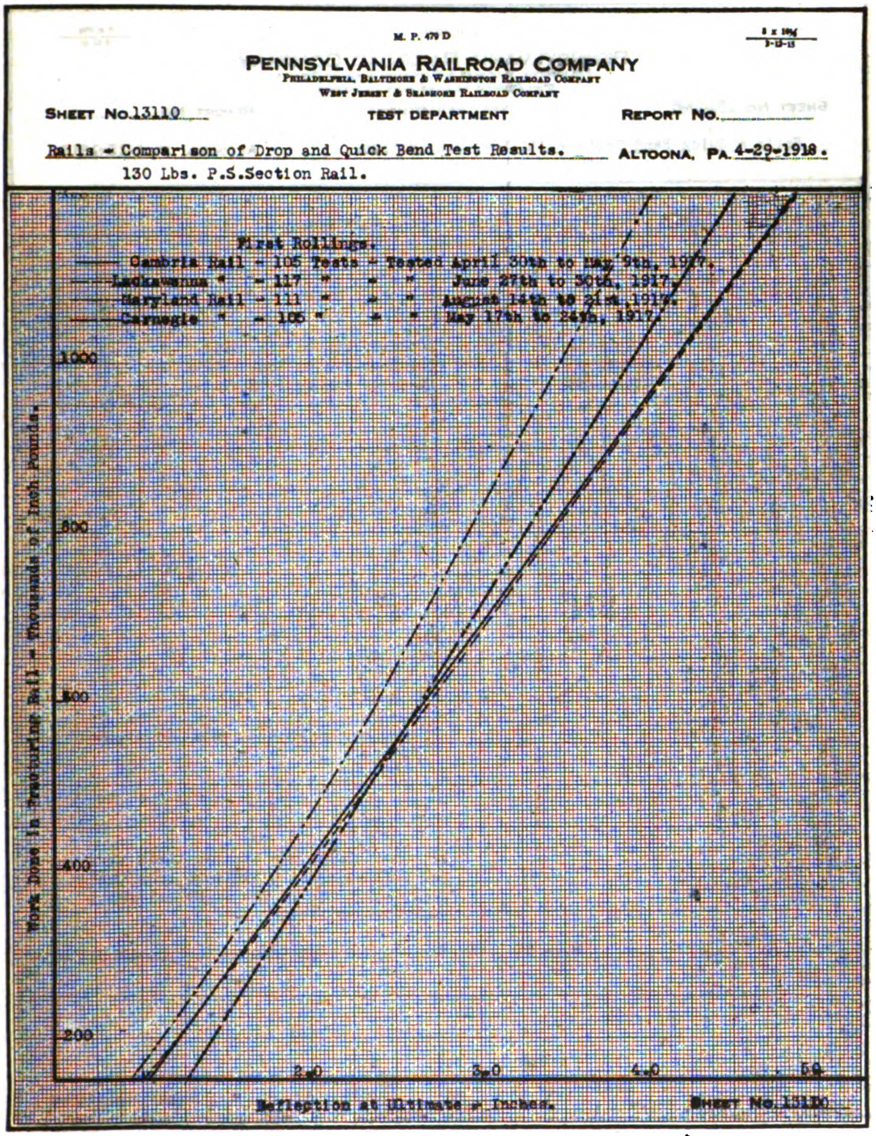


FIG. 9—DEFLECTION OF RAIL AS RELATED TO WORK DONE.

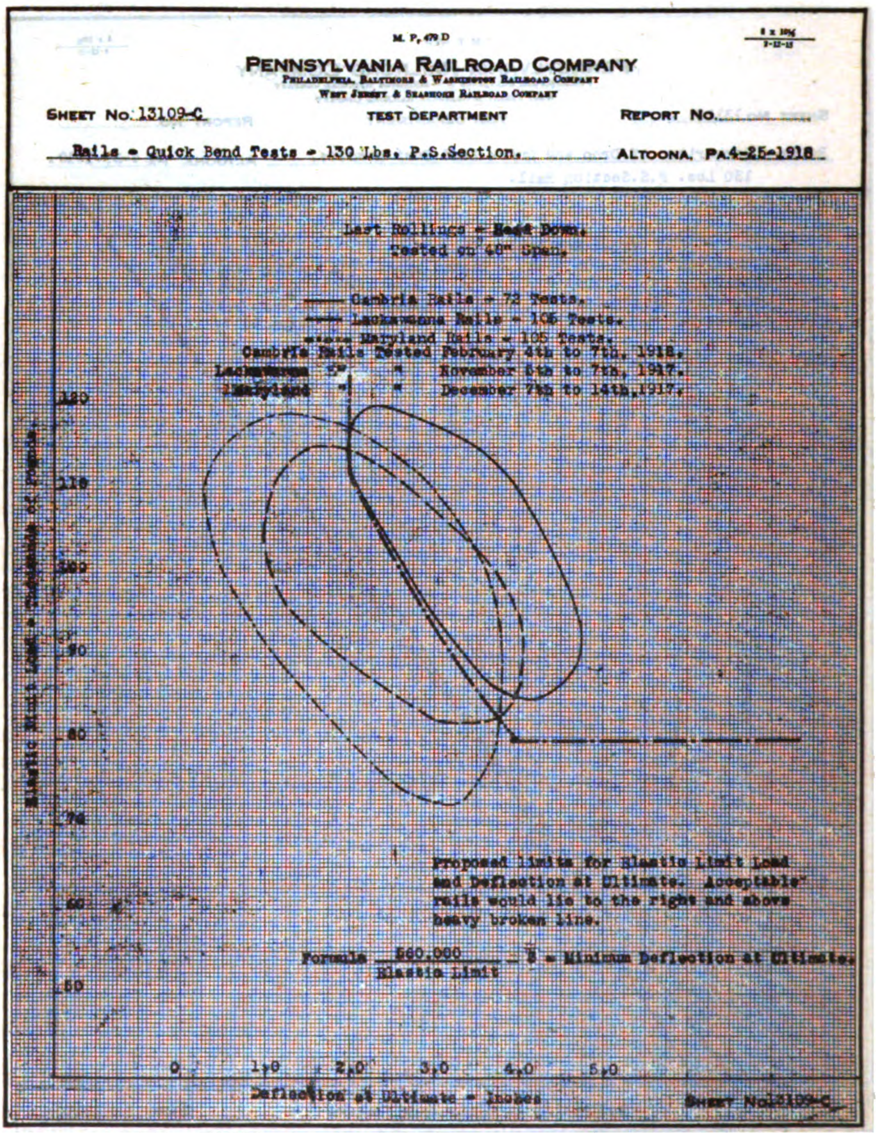
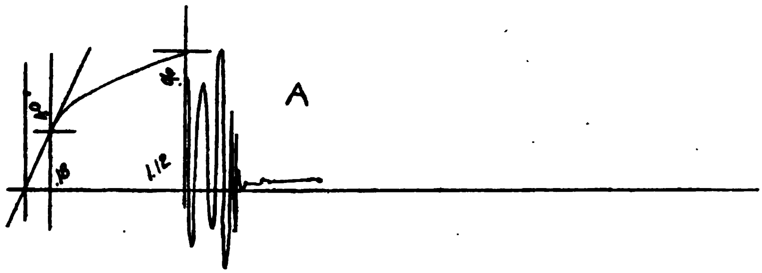


FIG. 10—DEFLECTION OF RAIL AS RELATED TO ELASTIC LIMIT.

to avoid brittleness in the rail, it was decided that perhaps the best comparison between different rail steels could be made by considering them on the basis of these two properties, at least for the present, until the opportunity is afforded for a closer study of the data. Numerous sheets like Fig. 10 have been prepared to show respectively the results obtained from the tests of the rails of the different mills of the first, middle and last rolling, and zones have been drawn to include the majority of the test results for each of the mills shown, the shape of the zone being based as closely as practicable on the density of the points within the area. The results in each case were quite variable, that is, did not show a direct



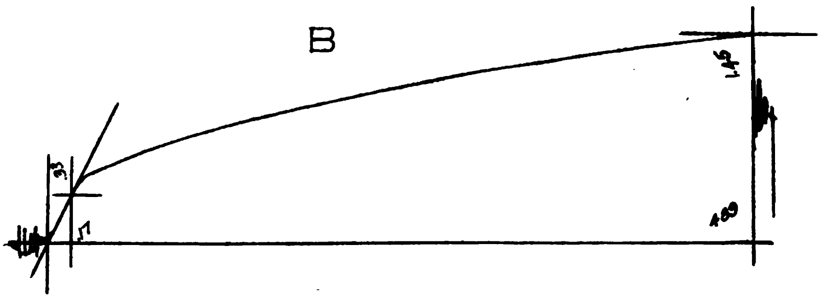


FIG. 11—INDICATOR CARDS FROM SOME REJECTED RAILS.
A IS ORIGINAL AND B IS AFTER ANNEALING.

relation in all cases between the elastic limit load and the deflection at ultimate, therefore it did not seem advisable to draw curves, but rather to indicate the variability of these properties by the area of the different zones. The principal differences brought out on these plots are as follows:

(a) There was a number of tests which gave points above all of the zones, and these high elastic limit points were always accompanied with low ductility, that is, small deflection at ultimate.

(b) The head-down tests made on the specimens representing rollings from three different mills, indicate certain characteristics which,

when compared on the basis of elastic limit and deflection at ultimate load, show well-defined differences between the rails from the different mills.

(c) It was brought out in the previous report (Proceedings, Volume 18, 1917, page 1081) that the elastic limit load of a rail is of primary importance in the determination of its stiffness and its wearing qualities. The indicator cards of the quick bend tests give an accurate record of the transverse elasticity of the steel, which information cannot be obtained in any manner from the drop test. A record is also obtained on the full ductility of the metal as shown by its deflection under the load up to the point of final break.

Indicator Cards.

Fig. 11 is supplied for information and is the reproduction of two cards obtained from rail specimens of the same heat. This heat was entirely thrown out, due to the fact that the test rails, a, b, etc., from first, middle and last ingots, all indicated brittle characteristics under the drop test, and when subjected to the quick bend test, produced stumpy cards similar to card "A" shown at the top of the photograph, which indicates brittleness. A specimen rail from one of these rejected ingots was annealed and then broken by the quick bend test. The card "B," shown at the bottom of the photograph, was obtained from this annealed specimen. Although the elastic limit load was about 15 per cent. lower than the original specimen, the work in thousands of inch-pounds to break the rail was approximately 330 per cent. greater. This merely shows how brittleness may be overcome by annealing.

Appendix I.

REPORT ON TRANSVERSE FISSURES.

By Dr. P. H. Dudley, for Sub-Committee on Transverse Fissures.

I have the pleasure to submit my report on Interior Transverse Fissures.

Government investigators class them as fatigue fractures of metal while the railroad officials have facts from their service records of rails which prove that they are not fatigue fractures of metal.

The Government investigators do not explain the origin, time and place of occurrence of the nuclei, nor the variation in size from $\frac{1}{16}$ to $\frac{3}{8}$ of an inch in diameter of the type of interior transverse fissures classified by me as intergranular. All fractures of this type show nuclei of considerable area, and that they are not points. These areas constituting the nuclei, rupture as a unit and not in detail, showing positively and conclusively that fracture was caused by the application of a rapidly applied blow of a pressure beyond the elastic limit, or even ultimate strength of this interior core of inferior metal.

(The argument has been advanced that cast iron wheels with long flat spots could furnish this required blow for checking the nucleus, which is not the case. The effect of this type of blow is to increase the compressive stress in the rail head, while the tensile strains of the base simultaneously increase. The fracture of all nuclei of fissures of the intergranular type shows them to have been ruptured by tensile stress, and this is only possible when the rail head is momentarily placed in tension, as when a low rail from the hot beds is straightened by the gag in the straightening press.)

The Government investigators conclude that the fracture of the nucleus and the subsequent development constitutes a fatigue fracture of metal, but as they occur only in an occasional rail head of like design, under the same traffic conditions, the railroad officials do not accept this statement.

There is, however, no difference of opinion between the railroad officials and the Government investigators about the growth in the track of the specular surfaces which start from and around the nuclei of interior transverse fissures.

Rail Report 77, January, 1919.

A REMEDY IN MANUFACTURE FOR REDUCTION OF INTERIOR TRANSVERSE FISSURES.

I have mentioned in previous communications to the Rail Committee that rails rolled from reheated blooms did not develop as many interior transverse fissures in the track as rails rolled direct from the ingots. I have collected the service records of eight railroads designated by Nos. 21 to 28 inclusive. (Exhibit A.) These reported 559,644 tons by direct rolling for the years 1909 to 1915—given in detail per year—and 1054 interior transverse fissures were developed. The railroads also reported 322,593 tons from reheated blooms which developed only 59 interior transverse fissures. The rails were rolled at 11 different mills and are numbered from 1 to 10 inclusive, though No. 4 has a mill designated by No. 4a.

Personally I know some of the early basic open hearth rails were made under difficulties for reheating the blooms before the mills were regularly equipped to manufacture this grade of steel into rails, and several of the interior transverse fissures in the reheated blooms are due to this irregular mill practice. The carbon content of some rails was also higher than would be used at the present time in these weights and sections.

The railroad companies are to be congratulated that the Rail Committee statistics of the service records of rails show at the present time a remedial method of manufacture of rails *which at least reduce the interior transverse fissures 90 per cent. in the output.*

INVESTIGATIONS.

There were more Engineers of Tests engaged in the investigations of interior transverse fissures in 1918 than in any preceding year. This is due to so many officials of the railroads who have found from the service records that some brands of rails in the track had a large number of failures, while other brands rolled under a different mill practice, did not have one failure in the same section, and subject to the same wheel loads and tonnage. The repetition of such records from year to year impresses the minds of officials, tracing the facts, and they are forced to the conclusion that there is something in the manufacture of the rail which contributed to the several interior transverse fissures in one brand and none in other brands of rails for the same service. *This general fact has led to extensive investigations of the quality of the metal in the interior of the rail heads.*

Those of Mr. F. M. Waring, Engineer of Tests of the Pennsylvania Railroad, are of so much value that I report them to the Rail Committee just as he submitted them to his superior officer, and they are appended to my report as Exhibit B. These partake of the nature of the etching tests for checks in the interior metal of the rail head conducted by Mr. M. H. Wickhorst, in charge of investigations for the Rail Committee. They are made by a different method of etching, and are a confirmation of abnormal metal in the interior of the rail heads which have developed interior transverse fissures in the track, but not in those rail heads which

rendered good service. This is valuable and to be expected in a research made to determine facts.

The investigation of interior transverse fissures in rail heads has been and will be difficult for most investigators. Each process of manufacture at the mill must be checked by every known method of research for the physical properties of the metal are affected and may be ductile or brittle for the chemical composition, so that some of the usual methods of testing will show negative results.

Mr. J. B. Young, Chemist and Engineer of Tests, P. & R. Railroad, also reports finding cracks in several tensile specimens which were made from new rail; the specimens were selected at the hot saws before the rails had been cambered, cooled on the hot beds, or placed in the straightening presses. Nearly all specimens show only about 2 per cent. ductility of the metal in the interior of the rail head, while the photomicrographs indicate clearly the cracks within the steel. The information and photomicrographs on these tests are given as Exhibit C.

Mr. M. H. Wickhorst has conducted complete investigations on three melts of steel of different manufacture, in which interior transverse fissures developed in service. These are given as Reports Nos. 71, 72 and 74.

Mr. Geo. F. Comstock, Metallographist of the Titanium Alloy Manufacturing Co., has completed investigations connecting the nuclei of the intergranular type of fissures with high phosphorus streaks in the interior of the rail heads.

The identification of types and classification which I made have been published in the proceedings of the American Railway Engineering Association. See Reports to Rail Committee, annual convention, 1915, and Nos. 59 and 68.

I have also recently conducted extensive tests and surveys on rails by means of an improved type of magnetic rail tester. The leakage curves of rails by this testing apparatus furnish a fund of information about the physical properties in rails and the serious disturbance of the metal in the heads and bases of rails by the gag of the press to straighten the rails in the finishing department of the mills.

There is another type of fissure in which the nuclei are shrinkage cavities and have been found in Bessemer rails made where the ingots were cast in pits before the converters and laid down upon cars to be transported to the horizontal reheating furnaces. These are of interest only as to the cause; the mill practice of teeming the ingots on cars and transporting them vertically to the reheating furnaces has been installed at all mills since the date of making those Bessemer rails. For complete information see Exhibit D.

COLD ROLLING AND INDUCED BRITTLENESS OF METAL.

I have written in previous papers about the brittleness of the metal in rails induced by cold rolling which I wish to illustrate, using Mr. F. M. Waring's diagram of brittle steel as shown by the Quick Bend Test. When the rail section was annealed, the toughness of the metal was restored, as shown by the subsequent diagram. See Exhibit E.

One mill, some years ago when metallographers advocated cold rolling and finishing, was constructed to hold the rails 40 seconds before the finishing pass. The rails developed brittleness under the drop, and the 40 seconds was cut to 20. Still some rails were brittle, and the latter time of holding the bar was eliminated.

One of these cold rolled rails was laid in a yard track at the Grand Central Station, New York, and broke the first winter. I placed a ¾-inch octagon point spike maul on the web of a piece of 6-inch 100-lb. rail, and with seven blows of a 20-lb. sledge shattered the rail. A piece about 7 ft. long was then annealed in a wood fire and it required 334 blows of the 20-lb. sledge to drive the point of the spike maul through the web without any other injury to the rail. The physical properties of the metal were restored in toughness by its annealed condition without change in its composition.

Rails by direct rolling are often delayed in some of the passes of the roll trains and are reduced in temperature which is not restored before they arrive at the hot beds for cooling. The bar is often reduced from 20 to 30 per cent. per pass before the last one in the finishing train. The stretching of the interior metal of the rail head is done in a small fraction of a second as the bar is drawn through each roll pass.

I also include a cut of two rails tested under the drop. See Exhibit F. The metal was brittle the entire length of the upper rail illustrated in the cut. There were two well developed interior transverse fissures near the center of the rail head of the intergranular type, and three more of the same type which had started to develop, one core and a small coalescent type, which gives the full history of the type of rail from the hot beds and the work of the gag to straighten the rail. Ninety-six of the 329 rails tested under the drop for brittle metal in the interior of the rail head fractured in a similar manner to the one illustrated. The lower rail illustrated in the cut was brittle only in the vicinity of the coalescent type interior transverse fissure, while the balance of the rail withstood several impacts of the falling weight without developing fracture. One hundred and one of the 329 rails drop tested were of this character. There is an intermediate type between the two illustrated in which the rail is brittle for a portion of its length while the balance shows ductile metal. Generally one-half or more of the rail length shows brittleness and the balance toughness. One hundred and thirty-two of the 329 rails tested were of this general type. All tests were made with the head in tension so that the hardened bearing surface of the rail head was subjected to the greatest amount of stretch.

It is evident from the experience in the manufacture of basic open hearth rails and their service that the chemical composition has more influence on either the physical property of toughness or brittleness of the rail heads than is generally appreciated.

(a.) When the chemical composition for the steel is below the eutectoid, the intended physical property of toughness may be modified in rolling or in the partial heat treatment of cooling on the hotbeds with the tendency for an occasional rail to be brittle.

(b.) When the chemical composition for the steel is above the eutectoid, the control of the intended physical property of toughness is not retained in rolling or in the partial heat treatment of cooling on the hot beds, and the metal of several rails are liable to be rendered brittle.

(c.) This is particularly true of rails rolled direct from the ingots.

This is a technic investigation of rail failures which more than justifies the existence of the American Railway Engineering Association.

Exhibit A.

COMPARISON OF RAILS ROLLED DIRECT AND FROM REHEATED BLOOMS.

ROLLINGS BETWEEN 1909 AND 1915. TOTAL TONNAGE ROLLED AND TOTAL FAILURES CHARGED AGAINST EACH ROLLING UP TO OCTOBER 1, 1918.

TABLE 1—INTERIOR TRANSVERSE FISSURES.

COMPARISON OF RAILS ROLLED DIRECT AND FROM REHEATED BLOOMS.

RAILROAD	SECTION	MILL	DIRECT ROLLED		REHEATED BLOOMS	
			TONNAGE	FAILURES	TONNAGE	FAILURES
ROLLED IN 1909						
No. 25........	100	No. 5	2600	1	......	..
No. 26........	100	No. 4	......	..	3400	0
No. 27........	100	No. 3	......	..	2600	0
No. 25........	100	No. 2	2176	18	......	..
No. 25........	100	No. 4	......	..	10276	1
No. 25........	100	No. 5	6162	4	......	..
		Totals	10938	22	16276	1
ROLLED IN 1910						
No. 27........	100	No. 3	......	..	10000	0
No. 25........	100	No. 4	......	..	5400	0
No. 22........	100	No. 5	14000	15	......	..
No. 25........	100	No. 5	13100	73	......	..
No. 25........	100	No. 5	13884	93	......	..
No. 23........	100	No. 6	6492	38	......	..
No. 25........	100	No. 2	6758	118	......	..
		Totals	54234	338	15400	0
ROLLED IN 1911						
No. 27........	100	No. 3	......	...	6500	3
No. 25........	100	No. 4	......	...	6100	9
No. 25........	100	No. 4	......	...	6283	9
No. 21........	101	No. 3	......	...	2038	0
No. 26........	100	No. 4	......	...	5105	1
No. 22........	100	No. 7	6216	1	......	..
No. 25........	100	No. 5	5800	14	......	..
No. 25........	100	No. 5	6072	20	......	..
No. 24........	100	No. 5	4906	42	......	..
No. 21........	101	No. 2	8277	30	......	..
No. 25........	100	No. 2	2270	20	......	..
No. 24........	100	No. 2	3960	9	......	..
No. 21........	101	No. 6	3541	3	......	..
No. 25........	100	No. 6	19836	92	......	..
		Totals	61021	231	26026	22

Table 1—Continued.

ROLLED IN 1912

No. 27.........	100	No. 8	......	...	9951	0
No. 21.........	101	No. 8	......	...	2202	0
No. 22.........	100	No. 4	......	...	15500	0
No. 25.........	100	No. 4	......	...	10800	2
No. 26.........	100	No. 4	......	...	26087	3
No. 22.........	100	No. 3	......	...	1097	0
No. 26.........	100	No. 10	......	...	3919	1
No. 22.........	100	No. 2	3800	0	......	..
No. 21.........	101	No. 2	3896	20	......	..
No. 23.........	100	No. 2	7806	0	......	..
No. 25.........	100	No. 5	20500	18	......	..
No. 26.........	100	No. 5	10803	86	......	..
No. 24.........	100	No. 5	11060	8	......	..
No. 21.........	101	No. 6	14741	80	......	..
No. 23.........	100	No. 6	35545	35	......	..
No. 28.........	100	No. 4a	4531	2	......	..
		Totals	112682	249	69556	6

ROLLED IN 1913

No. 27.........	100	No. 8	......	...	18068	6
No. 21.........	101	No. 8	......	...	8768	2
No. 22.........	100	No. 4	......	...	12262	1
No. 25.........	100	No. 4	......	...	6700	1
No. 26.........	100	No. 4	......	...	19940	1
No. 22.........	100	No. 3	......	...	2682	2
No. 27.........	100	No. 2	2720	1	......	..
No. 23.........	100	No. 2	5100	4	......	..
No. 21.........	101	No. 2	800	0	......	..
No. 23.........	105	No. 2	10054	5	......	..
No. 25.........	100	No. 5	3200	2	......	..
No. 25.........	100	No. 5	16991	3	......	..
No. 24.........	100	No. 5	17824	2	......	..
No. 21.........	101	No. 6	9842	88	......	..
No. 23.........	105	No. 6	60625	38	......	..
No. 22.........	100	No. 7	5670	1	......	..
No. 23.........	100	No. 4a	7105	0	......	..
		Totals	139931	144	70831	13

ROLLED IN 1914

No. 27.........	100	No. 8	......	...	5586	0
No. 21.........	101	No. 8	......	...	4376	1
No. 21.........	105	No. 8	......	...	4007	2
No. 22.........	100	No. 4	......	...	8400	0
No. 25.........	100	No. 4	......	...	12800	0
No. 23.........	100	No. 4	......	...	4894	0
No. 23.........	100	No. 3	......	...	2304	0
No. 21.........	105	No. 2	......	...	1809	10
No. 23.........	105	No. 2	......	...	2009	1
No. 22.........	100	No. 2	4125	0	......	..
No. 21.........	101	No. 2	316	0	......	..
No. 25.........	100	No. 5	17471	4	......	..
No. 25.........	100	No. 5	13400	0	......	..
No. 24.........	100	No. 5	9999	1	......	..
No. 21.........	101	No. 6	4431	52	......	..
No. 21.........	105	No. 6	2000	3	......	..
No. 23.........	105	No. 6	34680	4	......	..
No. 22.........	100	No. 7	4050	0	......	..
		Totals	90481	64	46126	14

TABLE 1—Continued.

ROLLED IN 1915

No. 27........	100	No. 2	......	...	3100	2
No. 23........	100	No. 2	......	...	4866	0
No. 21........	101	No. 2	......	...	2809	0
No. 31........	105	No. 2	......	...	2349	0
No. 28........	105	No. 2	......	...	3084	0
No. 27........	100	No. 3	......	...	5294	1
No. 21........	105	No. 3	......	...	2741	0
No. 22........	100	No. 4	......	...	13744	0
No. 25........	100	No. 4	......	...	26800	0
No. 26........	100	No. 4	......	...	10107	0
No. 22........	100	No. 3	......	...	2045	0
No. 25........	100	No. 5	12600	0	......	..
No. 25........	100	No. 5	18856	4	......	..
No. 24........	100	No. 5	20986	1	......	..
No. 21........	105	No. 6	4579	0	......	..
No. 23........	105	No. 6	30990	1	......	..
No. 22........	100	No. 7	3356	0	......	..
		Totals	91367	6	78939	3

TABLE 2—SUMMARY.

COVERING RAILS ROLLED DURING 1909 TO 1915.

DATE ROLLED	DIRECT ROLLED		REHEATED BLOOMS		RATIOS OF FAILURES (Equal Tonnage Basis)
	TONNAGE	FAILURES	TONNAGE	FAILURES	
1909.........	19938	22	16276	1	31 to 1
1910.........	54224	338	15400	0	338 to 0
1911.........	61021	231	25966	22	4½ to 1
1912.........	112682	249	69556	6	26 to 1
1913.........	139931	144	70831	13	5½ to 1
1914.........	89481	64	46125	14	2 3 to 1
1915.........	91367	6	78939	8	1.7 to 1
Totals.....	559644	1054	322593	59	10 to 1

EXPLANATION OF FAILURES IN RAILS ROLLED DIRECT AND FROM HEATED BLOOMS.

Some rails rolled direct during 1909 were finished so cold that the steel was brittle, and the attention of the mill superintendent was called to that fact. These rails were made from ingots with a 20 per cent. discard, and rolled during the warm weather period of July. This large discard and favorable weather condition did not prevent the development of a number of fissures in service. Brittleness of steel has also been found extensively in rollings of other years subsequent to 1909.

Regarding the rails rolled from reheated blooms, 27 of the 59 failures are from one mill though on several railroads.. These failures all developed in this mill's product prior to the time when their present uniform and good practice was established. No failures have developed in this mill's rails since 1913, so far as the records of the eight heavy traffic roads reported are concerned.

Ten failures listed in the 1914 analysis were from another mill which was in the process of reconstruction at the time those rails were rolled.

It is impossible to tell whether these rails were rolled direct or from reheated blooms, and therefore should be classed as doubtful.

Statistics have not been gathered from all roads nor for all weights of rail. Ten of the heaviest traffic roads in the country were requested to furnish data on interior transverse fissures in their section of 100 to 105-lb. weight. The failures in sections of lesser weight are considerably below those of the above mentioned sections, and there is also nearly a practical absence of this type of failure on light traffic roads.

Exhibit B.

INVESTIGATION OF TRANSVERSE FISSURES IN FAILED RAILS.

Altoona, Pa., September 25, 1918.

Mr. J. T. Wallis,
Genl. Supt. Motive Power.

Dear Sir:

We have been working for some time on investigations of failed rails, with particular reference to such rails as have failed from transverse fissures. During the past few months we have developed some information which appears to be sufficiently important to warrant making a progress report and bringing this to the attention of Mr. A. W. Gibbs, Chairman of the Pennsylvania Lines Rail Committee, with a view to having this committee consider the data and co-operate with us in outlining a series of further experiments upon new and old rails to obtain further information.

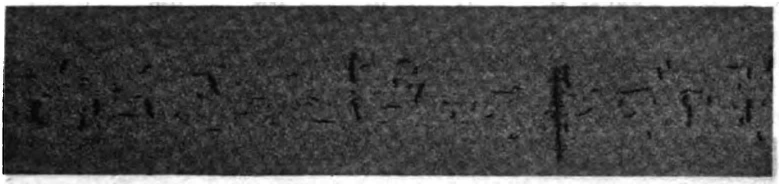
Briefly, our investigations have developed the existence of interior defects in the rail head which appear to be more frequent in rails that have developed transverse fissures than in rails which did not have such fissures. It appears that these concealed interior defects cannot be detected by the usual methods of investigation and tests, or even by the usual methods of etching. They have also been found to exist in a new rail which had not been in track and we believe that the evidence warrants the tentative opinion that these defects are produced during some process of manufacture.

Subsequent to your report of November 28, 1917, to Mr. R. Trimble, giving results of tests on 61 rails rolled by the Illinois Steel Co., from heat No. 31531, which report was later summarized by Mr. M. H. Wickhorst, Engineer of Tests, Rail Committee, in report No. 71 to the American Railway Engineering Association, March, 1918, we took some specimens from certain rails in this heat and continued our investigation.

It had been brought out in several previous reports to the American Railway Engineering Association that slight interior defects having the appearance of hair cracks have been developed on a section through the heads of some rails by very careful polishing and etching. We tried this method, but did not obtain satisfactory results with the most careful polishing and repolishing and etching with all of the usual etching solutions. We then decided to change the method and to apply a more drastic etching process.

Horizontal longitudinal sections were cut from the center of the rail heads; these were polished in the usual manner and then subjected to etching in successive solutions of iodine, picric acid, nitric acid and copper ammonium chloride. None of these etching solutions developed any physical defects. The slabs were then cleaned and subjected to etching for two hours in a solution of 9 parts of hydrochloric acid, 3 parts sulphuric

acid and one part of water, the solution being kept at a temperature of approximately 200 degrees F. The developments from this process were fully marked and unexpected.



PHOTOGRAPH T-10396.

Photograph T-10396 shows the appearance of a slab from the head of rail No. 38, heat No. 31531, in which both transverse and longitudinal cracks have been fully developed. This rail had a chemical composition of

C	Mn	P	Si	S
.869 at 0				
.787 at M	.74	.023	.115	.033

and when broken under the drop test had developed 12 transverse fissures.

PHOTOGRAPH T-10397.

Photograph T-10397 shows the etched slab from rail No. 32, heat No. 31531, which had the following chemical composition:

C	Mn	P	Si	S
.855 at 0				
.805 at M	.74	.025	.096	.03

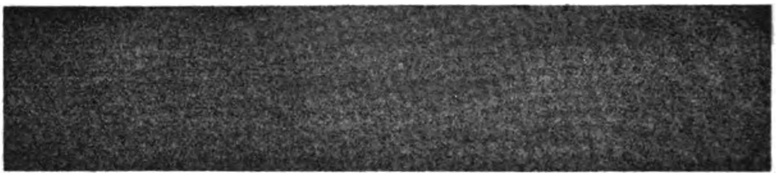
and had 10 breaks under drop test, one of the fractures showing an internal transverse fissure, while the remaining breaks had a pronounced starring appearance as if the breaks had started from defects in the head.

PHOTOGRAPH T-10398.

Photograph T-10398 shows the appearance after etching of slab from rail No. 27, heat No. 31531, which had the following chemical composition:

	C	Mn	P	Si	S
.891 at 0					
.839 at M		.73	.03	.098	.036

and which broke into 10 pieces on the drop test without showing any transverse fissures, but with all of the fractures having a pronounced starring appearance.



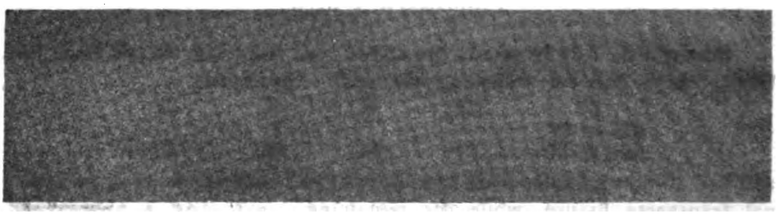
PHOTOGRAPH T-10399.

Photograph T-10399 shows the appearance of the etched slab from rail No. 29, heat No. 31531, which had a chemical composition as follows:

	C	Mn	P	Si	S
.808 at 0					
.873 at M		.66	.022	.191	.032

and which had shown excellent ductility under the drop test, the rail being bent without breaking at any point. In this slab there are none of the incipient cracks which were developed in the other rails.

A comparison of photographs T-10396, T-10397 and T-10398 show that the center portion of the respective rails contained defects which



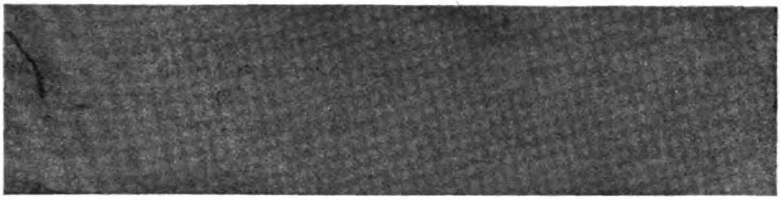
PHOTOGRAPH T-10400.

have been enlarged by the etching process. The number of such defects decreases with the decrease in the number of transverse fissures which were developed under the drop test, and with an increase in the ductility of the steel. Since these rails were all from one heat, of a fairly uniform chemical composition, and rolled at the same time, and since they were all subjected to approximately the same amount of service in the track, it would appear as if these defects found in the rail heads are associated in some manner with the process of manufacture.

In order to ascertain whether a new rail that had never been in track would show the same defects, we made the same etching tests on a piece of open-hearth P. S. Section 125-lb. rail of the following chemical composition:

C	Mn	P	Si	S
.704 at 0				
.680 at M	.69	.019	.159	.028

Photograph T-10400 shows the appearance of a slab from this rail after having been subjected to the action of a saturated solution of picric acid and alcohol. The appearance is very uniform and apparently free from internal ruptures.



PHOTOGRAPH T-10401.

This same slab was again etched in the hot hydrochloric-sulphuric acid solution, and photograph T-10401 shows that a number of internal transverse and longitudinal defects have been developed to visibility. The existence of these defects in a new rail points to their having been produced during manufacture.

An examination of all of these deep etchings brings out the fact that these small internal transverse ruptures correspond in their location and appearance with the nuclei of transverse fissures and it is possible that they may be the original cause of such fissure. The rail in service is subjected to alternate bending stresses and it is obvious that the presence of any transverse defect in the zone of these stresses would affect the strength of the rail and that the interruption of the continuity of the metal might cause the development of internal transverse fissures in detail formation starting from the edges of the existing defects.

The present investigation has only just been completed and the data are not conclusive, but indicate that further investigation should be conducted on both new and failed rails whose history is fully known. This with a view to developing the cause of the concealed defects which have been shown to exist in new as well as old rails and which apparently are produced in the steel at some time during the manufacture of the rail.

This progress report is submitted for the information of the Rail Committee and their co-operation is requested in outlining the scope for this investigation.

Yours respectfully,

F. M. WARING, *Engineer of Tests.*

Exhibit C.

Reading, Pa., November 27, 1918.

Mr. F. S. Stevens,
Engineer Maintenance of Way,
Philadelphia & Reading Railroad, Reading, Pa.

Dear Sir:

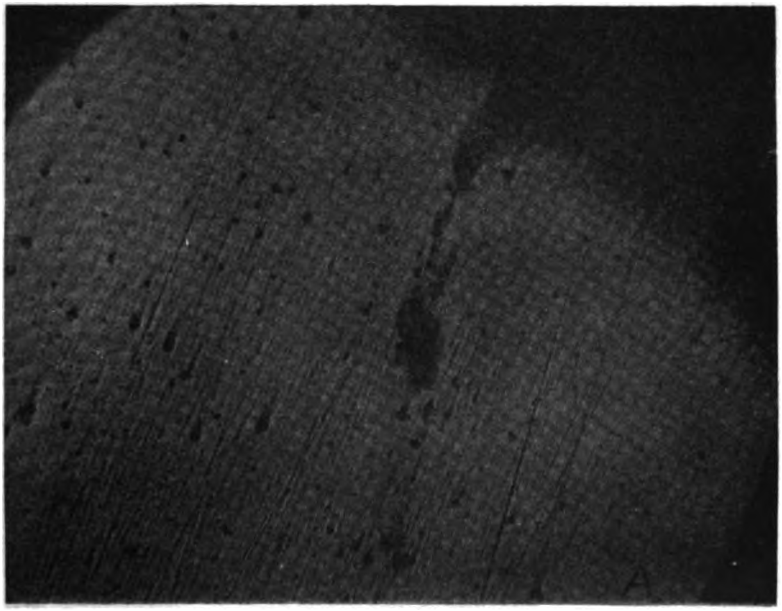
Referring to the subject of Transverse Fissures, I gathered from a discussion at the recent meeting of the American Railway Engineering Association Rail Committee that the Sub-Committee on transverse fissures had conclusive evidence that the fissures result from flaws which are in the rail before it is placed in the track.

I am sending you herewith some microscopic photographs of cross section of standard test specimens cut from the center of the head of our 100-lb. rail. The specimens were taken from a test section cut from the rail before it had even been on the hot beds; that is, this rail has not passed through the cambering machine or through the straightening presses. The cracks were noticed after the standard test specimen was fractured in the test machine. These photographs are conclusive evidence that flaws and cracks exist in new rails which have been subjected to no strains, except those developed in the rolling.

I would suggest that you submit these photographs to the chairman of the sub-committee on transverse fissures.

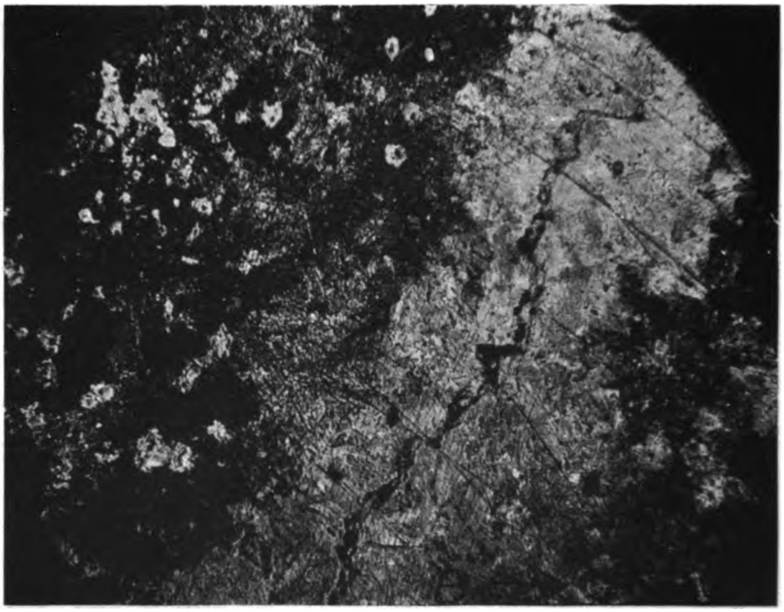
Yours truly,

J. B. Young, *Chemist.*



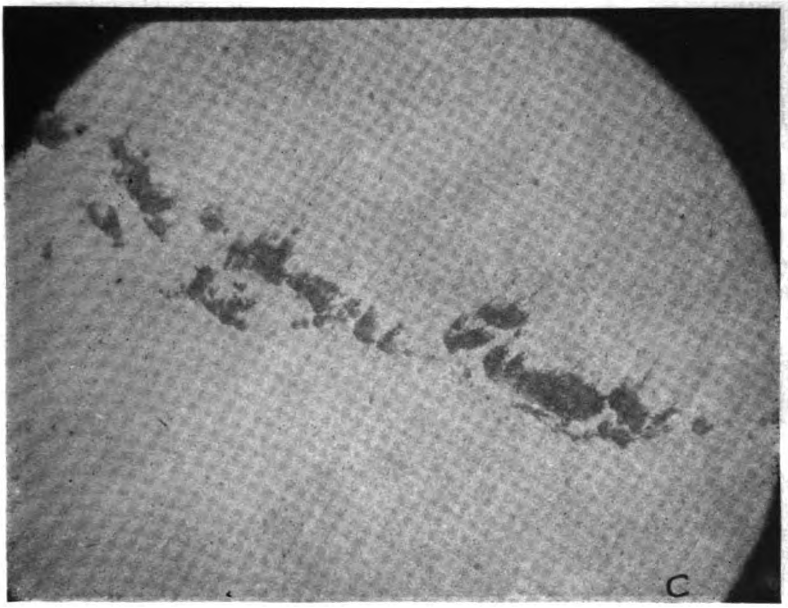
PIECE A. UNETCHED.

Piece "A." Unetched. x100. Heat, 5X1742, corner of head. Elastic Limit, 78,000 lbs. per sq. in. Ultimate Strength, 136,000 lbs. per sq. in. Elongation in 2 in., 3.0 per cent. Reduction of Area, 3.5 per cent.



PIECE B. ETCHED.

Piece "B." Etched in 5 per cent. HNO_3 in alcohol for 20 sec. x100. Heat, 2X1734, center of head. Elastic Limit, 83,700 lbs. per sq. in. Ultimate Strength, 123,500 lbs. per sq. in. Elongation in 2 in., 2.0 per cent. Reduction of Area, 3.0 per cent.



PIECE C. UNETCHED.

Piece "C." Unetched. x100. Heat, 4X1739, corner of head. Elastic Limit, 82,000 lbs. per sq. in. Ultimate Strength, 124,500 lbs. per sq. in. Elongation in 2 in., 2.0 per cent. Reduction of Area, 2.0 per cent.

converters, the track and cars upon which the ingots were laid in a horizontal position, were retained until the mill was dismantled.

The mill practice of transporting the setting ingots in a horizontal position on the car to the reheating furnace, would permit any shrinkage cavity to rise to the set columnar structure on the upper side of the ingot. I rolled over 500,000 tons of Bessemer rails from December 1892, to 1902, and out of that quantity, twenty-four interior transverse fissures have developed to date, and fifteen show porosity in the head, or traces of cavities as the nuclei of the fissures, while five rails were of the coalescent and four rails of the intergranular type. I made over a million tons of Bessemer rails in vertical teemed ingots charged into the vertical reheating furnaces from 1902 to 1911, and four interior transverse fissures have developed to date, from two different mills. Three fissures developed in the pioneer 5-inch, 80-lb. rail rolled in 1890, in which the man-

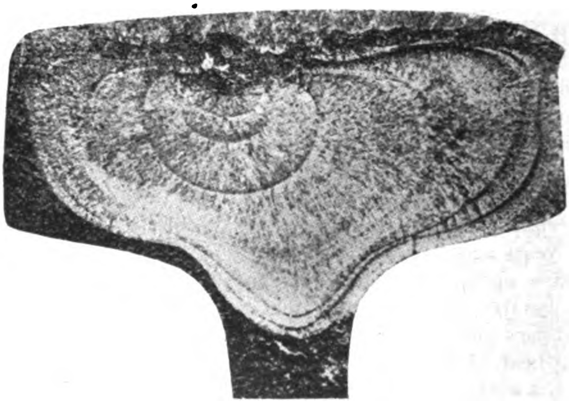


FIG. 69.

Specimen L-496-C. 6-inch 100-pound rail head. L. I. & S. Co., South Works. Bessemer steel. Heat No. 68188 "C" rail. Rolled July, 1897. Failed May 10, 1915. Nucleus of the interior transverse fissure.—Cavities.

ganese was over one per cent. This makes 32 Bessemer rails out of about 1,500,000 tons which have developed interior transverse fissures to date, of which there were nearly 1,000,000 tons in the Dudley design of sections and chemical composition.

These rare failures in the Dudley sections would be from about 2,500,000 Bessemer rails. Fifteen of these had cavities with serrated surfaces, visible ingot defects, due to a mill practice with the ingots, which has been discontinued by the mills, therefore, only of interest to us as to the cause. The abnormal conditions in the metal on the interior of the head, which have been found in the seventeen rails, still remain and are accentuated in the basic open hearth steel rails. This condition can be

overcome, as it is not common to all mills, or to all rollings from any mill.

I illustrated in my paper before the Mining Engineers, interior transverse fissures in which the nuclei were composed of well developed polyhedral crystals and at that time we had found them in nine different melts of steel. We have broken and split into small pieces one hundred and thirty-two rails from different melts to date and have found crystals in twenty-two.

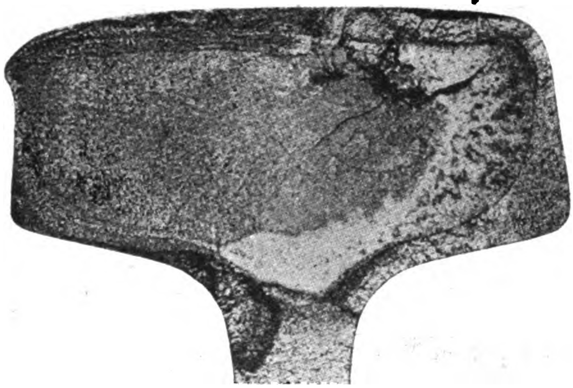


FIG. 70.

Specimen L-451-C. 6-inch 100-pound section. L. I. & S. Co., South Works. Bessemer steel. Heat No. 26011 "C" rail. Rolled July, 1897. Failed May 4, 1914. Nucleus of the interior transverse fissure.—Cavities.

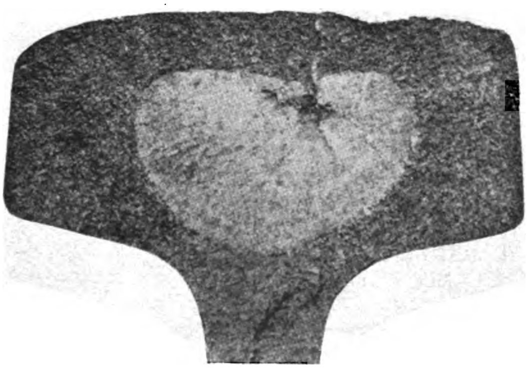


FIG. 71.

Specimen L-488-D. 5⅛-inch 80-pound rail head. L. I. & S. Co., South Works. Bessemer steel. Heat No. 359090 "B" rail. Rolled February, 1901. Failed March 3, 1915. Nucleus of the interior transverse fissure.—Cavities.

Grain growth to polyhedral crystals is the result of too long continued germinative temperature of manufacture rather than subsequent wheel loads in the track.

We have, as already reported to the Rail Committee, found delayed transformations in several rail heads, also cores, and non-ductible metal in other rail heads.

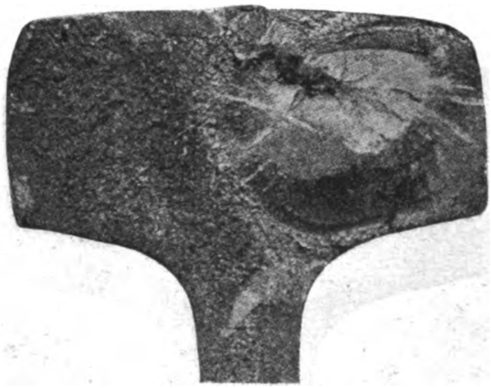


FIG. 72.

Specimen L-366-B. 5⅛-inch 80-pound section. L. I. & S. Co., South Works. Bessemer steel. Heat No. 3718. Rail letter—unknown. Rolled 1901. Failed May 14, 1914. Nucleus of the interior transverse fissure.—Cavities.

FIG. 73.

Specimen B-710-B. 6-inch 100-pound rail head. Bethlehem Steel Co. Open Hearth Steel. Melt No. 19785. "B" rail. Rolled July, 1909. Failed August 1, 1916. Nucleus of the interior transverse fissure.—Distinct polyhedral crystals.

Delayed transformations in the interior metal of the rail heads were positively confirmed by heating and cooling curves made on small pieces taken near the interior transverse fissures.

Abnormal physical conditions of metal in the interior of the rail heads were confirmed by tensile tests, and others are under investigation by magnetic tests.

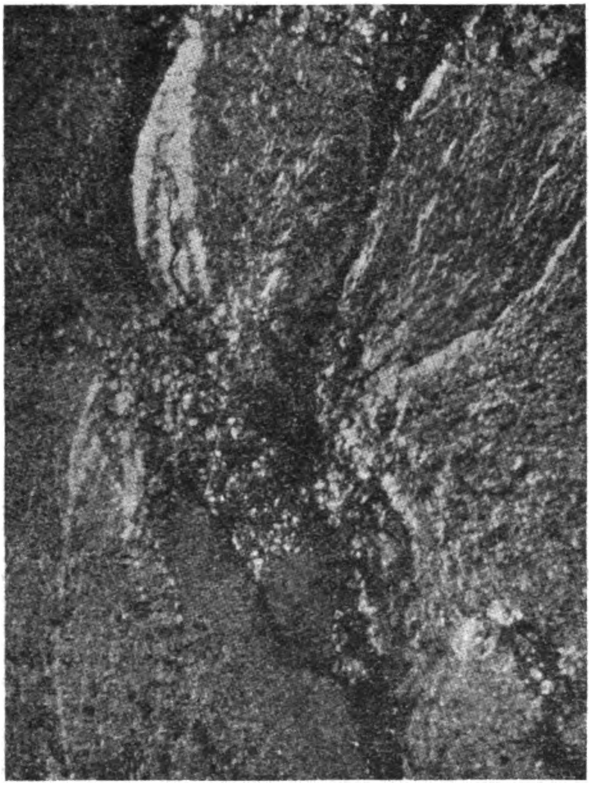


Fig. 74.

Same specimen as Fig. 73. The nucleus and crystals enlarged to 20 diameters.

Non-ductile metal in the interior of the rail heads has been confirmed by drop and tensile tests. Injury to the metal in the interior of the heads of rails by the gag has been indicated by magnetic tests.

Some one or more of the above conditions are found in rails which have developed interior transverse fissures in the track, while they are not found in rails which do not develop the same kind of failures, although doing the same amount of mechanical work to carry the same passing wheel loads.

Those who consider that the wheel loads cause the interior transverse fissures in the rail heads have not and can not explain the three

specific facts for the intergranular type—the difference in place, time and appearance of the fractured nucleus from that of the smooth specular surfaces which enlarge from its circumference, and for the coalescent type, the longitudinal serrated crack from which the transverse crack or nucleus develops in service.

Exhibit E.

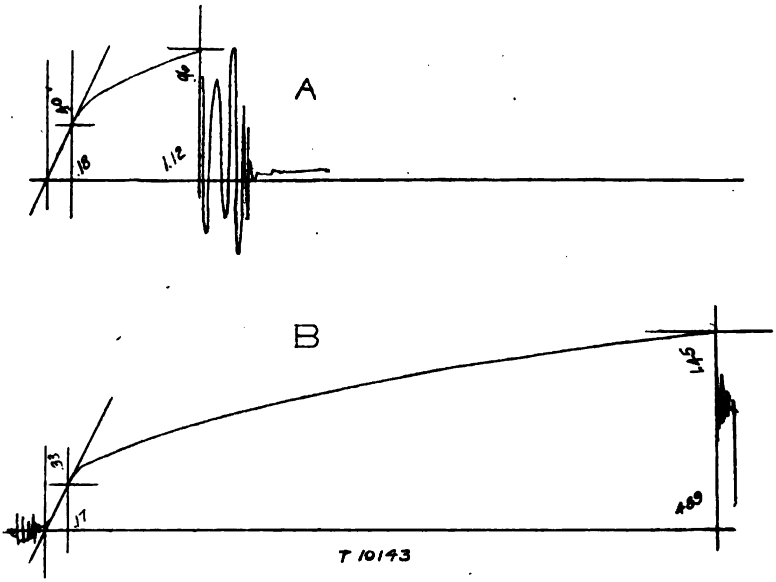
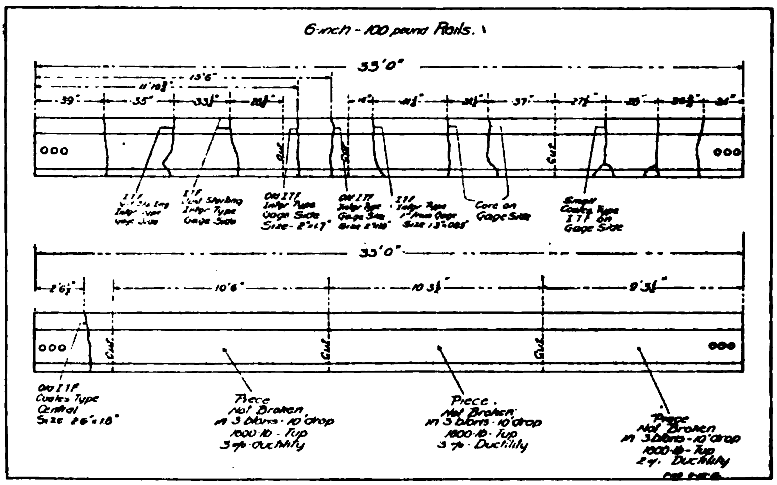


DIAGRAM A REPRESENTS A REJECTED RAIL AS TESTED AND DIAGRAM B REPRESENTS ONE FROM SAME LOT AFTER ANNEALING.

Exhibit F.



Appendix J.

REPORT ON EXTENT OF USE OF FRICTIONLESS RAIL AND RESULTS OBTAINED THEREFROM.

SUB-COMMITTEE I.

Your Committee was instructed to "Report on the Extent of Use of Frictionless Rail and Results Obtained Therefrom."

In accordance with those instructions, the Committee submits the following report:

(A) Extent of Use.

Your Committee has ascertained that the following steam railroads are using the Frictionless Rail:

Railroad.	*Date.*	*Mill.*	*Section.*
Maine Central	Aug., 1912	Bethlehem	85-lb.
Boston Elevated	Aug., 1912	Bethlehem	85-lb.
Chicago Junction	Oct., 1913	Bethlehem	85-lb.
Southern Pacific	Oct., 1913	Tennessee	9029
G. H. & S. A.	Oct., 1913	Tennessee	9029
Arizona & Eastern	Oct., 1913	Tennessee	9029
Met. West Side Elev.	Oct., 1913	85-lb. Comp.	Tenn.
Boston Terminal	Oct., 1913	Tennessee	9029
C. B. & Q.	May, 1914	Illinois	9029
D. L. & W.	April, 1914	Pennsylvania	304-101-lb. Comp.
A. & V.	Jan., 1914	Tennessee	9029
C. M. & St. P.	May, 1914	Illinois	9028
E. J. & E.	May, 1914	Illinois	9028
Illinois Central	May, 1914	Illinois	9028
Bingham & Garfield	May, 1914	Illinois	9028
Northern Pacific	June, 1914	Illinois	9028
P. & L. E.	Aug., 1915	Carnegie	96.5-100-lb. B Comp.
Canadian Pacific	May, 1915	Algoma	85-lb. C P R Comp.
N. Y. N. H. & H.	June, 1915	Lackawanna	932-100-lb. Comp.
Michigan Central	Aug. 1915	Carnegie	96.5-100-lb. B Comp.
St. Louis Terminal	June, 1915	Illinois	9039
Chesapeake & Ohio	Sept., 1915	Bethlehem	100-lb. Comp.
N. C. & St. L.	Oct., 1915	Illinois	9039
Pennsylvania Railroad	Dec., 1915	Pennsylvania	305
Lehigh & New England	Nov., 1915	Bethlehem	100-lb. Comp.
Miss. River & B. T.	June, 1916	Illinois	9039
St. L.-S. F. R. R.	July, 1916	Illinois	9039

The following electric roads have also made installations of the Frictionless Rail:

Mond Nickel Company.
New York Municipal Railway.
Connecticut Company
American Railways Company,
Interborough Rapid Transit Co.
Aurora, Elgin & Chicago Railway.
Springfield Street Railway.

Rail Report 78, February, 1919.

(B) Results Obtained.

In response to a circular of inquiry, the following replies were received, which are self-explanatory:

Railroad A.

Replying to your letter of November 25th, regarding use of Frictionless Rail, would advise that we have only used 30 tons of the companion rail for A. R. A., series B, weight 96.5 lbs. per yard, rolled by Carnegie Steel Company.

This rail was laid in two six-degree curves at west end of our ——— Bridge at ————, ———, where very little elevation of rails is possible account of slow speed. It has been necessary heretofore to renew the high rail every two years, but judging from inspection of a few months ago, it will be possible, with the use of the Frictionless Rail, to obtain at least four years' service from the high rail before renewal will be necessary. The Frictionless Rail is still in first-class condition, having been in service about three years.

We are very well pleased with the results obtained from the Frictionless Rail and would have gone more extensively into its use last season if it had not been practically impossible to secure small tonnages of special section from the rolling mills.

Railroad B.

Replying to your inquiry of the 25th ult., subject, "Use of Frictionless Rail."

Ans. Q. 1. The ——— purchased 154 tons of Frictionless Rail, companion to 90-lb. A. R. A. Type A Rail, in 1914, and 284 tons of the same section in 1915. This was all Open-Hearth rail, rolled by the Illinois Steel Co. at their Gary Plant. I believe that the rail has all been worn out and not replaced. The rail was installed on our —— Lines in ———.

I am asking our General Superintendent to give me some information or a report which would enable me to reply to your Question 2, and I will endeavor to have it reach you as quickly as possible, and I hope before December 31, 1918.

Under date of December 3rd, Mr. ——— wrote you and sent a copy of his letter to me, about the use of Frictionless Rail.

I have had the question up with our Division Superintendent on whose division this rail is in service and I have just received his report to the effect that the Frictionless Rail applied on the ——— Division, on curves 6 to 10 degrees, is not lasting as long as the ordinary rail applied on curves of similar degrees in the same territory. It is estimated that the ordinary rail we have in service in the same district will last approximately one year longer than the Frictionless Rail. Frictionless Rail is all in service on our electrically operated territory and it appears that the heavy motors we are running there mashes down the ball of the rail and makes it appear wavy. After it begins to mash down, it sounds bad, somewhat like a burned or blistered rail which may be caused by locomotives slipping. An examination of the rail, however, discloses that it is in safe condition and that there is plenty of metal left on the ball to support it. The only trouble being that it looks wavy and rides rough.

Our men do not recommend any more of this rail on this account. We find that its life is from two to two and a half years.

Railroad C.

Referring to your letter of the 25th instant, re use of Frictionless Rail.

In the Fall of 1915 this Company placed 198 tons of Frictionless Rail in our tracks for test purposes. This was a companion rail for our standard 85-lb. rail weighing 86 lbs. per yard, and was rolled by the Algoma Steel Corporation, at Sault Ste. Marie, Ont.

The first results were excellent, as there was a decided decrease in the flange wear on the outer rail and our operating people claimed that the installation permitted the handling of greater tonnage in the territory affected. Unfortunately the metal proved too soft to maintain the required narrow running surface and flowed and battered badly. This resulted in partially nullifying the test so that no conclusive opinion could be formed of the advantages of the Frictionless design.

It is my personal opinion, however, that the design of the Frictionless Rail is correct for the purpose for which it is intended, and that if the metal is sufficiently hard to retain its section, very excellent results will be obtained. The condition of the rail market has so far prevented my securing the necessary rail to test this opinion, but I hope to do so when conditions again return to normal.

Railroad D.

Referring to your letter of November 25th in regard to use of Frictionless Rail, wish to advise that we had 1058 feet of Frictionless Rail on 4 degree curve near ———. This was A. R. A. rail rolled by the Illinois Steel Company and was installed June 8th, 1914, and removed July 1st, 1917. The service was entirely satisfactory and we think the test was an entire success.

However, we find that by using on the low side of curves rail taken from the high side of curves and which is somewhat curve worn, it gives us about the same results as using the Frictionless Rail on the low side of the curve.

Railroad E.

We have approximately 750 tons of this rail in use weighing 79.6 lbs. per yard and rolled at South Bethlehem Mill of the Bethlehem Steel Company. The results obtained have been excellent where the rail has been hard enough to stand under the unit pressure of the wheel loads on the narrow head. The first rail of this character which we laid was rolled as an A. S. C. E. 85-lb. rail and was taken into our shop and the head planed down to the section desired by the inventors. These particular rails were open-hearth, high carbon steel, and an analysis made some three years ago of one of these rails showed the carbon content slightly over .80. These rails were installed on the low side of a main line curve, I think, in December, 1911, and were in constant use until January, 1918, when that section of track was abandoned as main line on account of a diversion. Standard section of rail on the inside of this curve had to be renewed about once in 20 months previous to the installation of the Frictionless Rail.

In 1912-13-14-15 and 16 we had 125 tons of this rail rolled to the full required section and it was used on some 25 curves through the ——— Mountains. Also on several curves a short distance east of ——— and in the vicinity of ——— and at other points and with somewhat varying results. It gives most excellent service where it is hard enough, and I believe we have never had one of these rails break under traffic. Nearly all of the rail as mentioned above is still in service. The principal features in favor of this type of rail as I understand the matter is the lessening of wear on the outside rail and the decreased tendency of the rail to cant outward, both of which claims seem to be substantiated by our experience with the rail.

Railroad F.

Replying to your letter of the 25th ult., this railroad had 585 tons of Frictionless Rail, 98-lbs. per yard, as a companion to our standard P. S. 100-lb. rail, rolled by the Pennsylvania Steel Co., Steelton, Pa., in December, 1915. This rail was installed in heavy curves on the eastern slope of the ——— Mountains between ——— and ———, and, at this time, it is practically all removed from track. We cannot say that it was much of a success, as the section of rail was too light for our heavy traffic between these points.

In May, 1918, we had 615 tons of Frictionless Rail, 125½ lbs. per yard, as a companion to our standard P. S. 130-lb. section, rolled by the Bethlehem Steel Co., at Sparrows Point, Md. Some of this rail is installed on our Middle Division, between ——— and ———, on the following curves: 1°, 1°15′, 2°, 2°45′, 3°50′, 4°, 4°30′, and 6°.

Some of this rail is also installed on our ——— Division, between ——— and ———, on curves of 2°, 3°, 5° and 6°.

My opinion is that it is entirely unnecessary to lay Frictionless Rail on curves under 4°. This rail has been in service too short a time to say whether the advantages will justify the additional cost.

In my judgment Frictionless Rail is justified for use on curves of 6° and over under heavy traffic conditions, especially for passenger service. Frictionless Rail avoids, to a considerable extent, the wearing of the outer rail on curves, and also furnishes a smoother riding track on heavy curves. With heavy freight trains, there is undoubtedly some reduction in the draw-bar pull with Frictionless Rail, as compared with the ordinary sections.

Railroad G.

Answering yours of November 25th requesting information for use of the Committee on Rail, in regard to use of Frictionless Rail, beg to advise as follows:

(1) We have about 110 tons of 93-lb. open-hearth Frictionless Rail, rolled by the Lackawanna Steel Company in 1915 and laid as companion to 100-lb. and 107-lb. rail—one heat is of 62 per cent. carbon and the other heat 69 per cent. carbon. This was laid on 6° and 6°20′ curve, a short distance east of ——— Passenger Station in September, 1915; on a 7° curve near ——— in July, 1917, and on a 9°30′ curve near ——— in October, 1917.

(2) There is no opportunity in these installations for a direct comparison of results with Frictionless Rail as compared with standard rail. The conditions at ——— in the eastbound train movement are very severe, on account of up-grade and trains being obliged to stop frequently due to drawbridge conditions, and the test, therefore, could not be considered entirely fair. The rail in this track was removed July, 1918. On the westbound track, rail stood up much better, and is still in service. A direct comparison with what would be the result with standard rail is not possible at this time. At ——— and ——— the tracks are not yet completed; however, the results so far have not proved entirely satisfactory, being much similar to those obtained at ———. The head of the Frictionless Rail flows considerably, particularly on the outside; the head becoming mushroomed out to the width of the standard head rail.

In regard to expression of opinion as to the advantages and disadvantages, in my opinion Frictionless Rail of the composition and hardness of that used by this road as above, is not sufficiently hard to prevent the head from flowing. It would be necessary to make rail of this type of a much higher grade of materials than that of the rails which we tested and if this is done, the Frictionless Rail would undoubtedly prove more serviceable, and probably have an advantage over the use of two rails of standard section.

Railroad H.

This road has one hundred tons of 90-lb. Frictionless Rail rolled by the Illinois Steel Company in the summer of 1914. The rail was laid in October, 1914, between Mile Posts Nos. 62 and 65, on various curves ranging from 4° to 12°, on a 2.2 per cent. grade.

The Frictionless Rail has now been in service four years and from recent inspection its condition would indicate that it is good for about two years more. The standard rail in these same locations lasted three years.

Our records would indicate that there is considerable less wear on the rails where the Frictionless section is used, but as yet we have not determined how much saving there may be, if any, over our established practice of changing worn rail from the high side to the low side.

Railroad I.

In reply to your letter of the 25th ult., relative to the use of Frictionless Rail, I beg to advise that we have about 20 tons of Barbey's Frictionless Rail on two curves on our ——— Branch, which is a companion rail for 90-lb. A. S. C. E. rail. This rail was rolled in August, 1915, by the Bethlehem Steel Company and was placed in our track in December, 1915.

I also hand you a copy of my letter of November 22nd, 1917, and beg to advise that there has been no change in this rail since that letter was written. I consider that we have had good results from the rail, but regret that it was not of higher carbon.

Referring further to your circular letter of August 3rd and my reply of August 14th.

I enclose herewith data of typical curve of which we have Barbey's Frictionless Rail on the low side. In addition to this I beg to advise that we have a ten-degree curve on a practically level grade laid with this Frictionless Rail.

I enclose a blueprint showing the rail sections taken as indicated by the dates shown thereon.

The Frictionless Rail as laid is not a companion rail to the ASCE 90-lb., but I believe it is a companion rail to 100-lb. ARA-B and you will notice are low carbon, but we were anxious to try them out, and taking everything into consideration, the results lead me to believe that a rail of this type from .70 to .75 carbon would give excellent results. In the operation of our road we double the grade, at the foot of which is located this curve; since the installation of the Frictionless Rail we have been enabled to pull a tonnage train several hundred feet further before cutting off and doubling, otherwise I have not seen any financial returns, unless it would be in the maintenance, but the curve is so short it would be hard to determine just what that is.

Railroad J.

Replying to your request for statements on the Barbey rail for low side of curve, I may say that I am acquainted only with the use of this rail on the ———, ——— and ———. The results from its use on these roads has been of pronounced advantage except in a few cases of soft melts of steel where flow of metal has occurred to some extent.

The prevention of flange cutting of the high rail is the real office of this rail and where the conditions are right it has been very effective in this service in all the cases with which I am acquainted.

The roads mentioned above will probably make reports of their experience so that it is not necessary for me to give data for particular curves, but I can say that the life of rails is generally greatly increased

and the resistance to traction decreased on curves where these rails are used. The decrease in train resistance is due of course to the elimination of the work so commonly done in flange grinding on the high rails and the length of life follows from the same fact.

The efficiency of the rail depends on the wheels rolling regularly in the position of least resistance and truly in one position on the rail heads. If the ties are new at the joints and worn so that the rail is canted more at centers than at joints the trail of the wheels will wander from side to side of the rail head and the proper efficiency will not be obtained.

The best results are obtained when the gage is opened from 3/16ths inch to 5/16ths inch and when the elevation is no greater than is needed to obtain fair riding at the maximum speed on the particular curve in question. No superelevation is needed for low speed. Curves of three degrees and over should be eased by spirals.

The tendency of manufacturers is to roll these rails from melts of rather low carbon from fear of rejection by the drop test if the carbon is a little high. As a matter of fact, these rails will safely stand higher carbon than standard shapes on account of the better rolling effect on the narrow head. It may be that a narrow head will suffer more from flow due to heavy wheel pressure than a wide head, but with equal carbons this is questionable.

My observations convince me that where the conditions are right the results following the use of the rails are very pronounced in the two factors of prolonging the life of the outer rail and in decreasing train resistance on curves. Much less maintenance work is required also than with standard shapes. These features bulk large in economy, but of course are offset in some degree by the bother of odd relays, step joints, etc.

Railroad K.

We have placed in track 22,400 ft. of Frictionless Rail; 7,470 ft. of which was of the section shown on plan 37727 and 14,930 ft. of the section shown on plan 38878-A, both attached. Both were 90-lb. rail manufactured by the Illinois Steel Company. All of this rail has been removed from track except that in one curve near ———, where a total of 1,500 ft. of Frictionless was laid in October, 1915, and is still in service, but will have to be changed out next year. All of the rail we moved had developed excessive flow of metal and on the ——— Hill there were quite a number of split heads.

My conclusion regarding the merits of this rail are summed up in a letter of December 7th, 1917, as follows:

"Rail Wear:—All tests indicate that Frictionless used as the low rail on curves does not give longer service than standard section when rolled from same quality of steel, but by reducing the friction against the outer rail does protect that rail materially against abrasion. It is the general opinion of the trackmen that outside curve-worn rail will give equal or better results than Frictionless when used as the low rail. This bears out the conclusions expressed in a letter written May 3, 1916, as follows:

"I have thought that curve-worn rail taken from the outside of a curve, when the rail is considerably worn, and put on the inside would give the same frictionless results as a rail made especially for that purpose, and would have the further advantage of being hardened on top by traffic, and would probably not flow or wear as fast as a new rail.

"Tonnage:—Our investigations indicate that a narrow head rail used on the inside of a curve makes it possible to handle more tonnage with the same power. Our tests were not precise enough to justify any definite conclusions as to the percentage of increase that might be expected.

"Based on the above conclusions it is recommended:

"First. That so far as is practicable in relaying curves with rail of the same weight, the high rail be thrown over and used on the inside.

"Second. That when conditions become normal, we consider the question of re-rolling worn rail into Frictionless shapes as is being done by the American McKenna Process at Joliet.

"Third. That we consider the rolling of a small tonnage of Manganese Frictionless or other special steel for such curves as the ———, the 12-degree curve at ——— and the ——— and ——— curves on ——— Hill and for the curves approaching the bridges at ———, ———, ——— and ———. (This last recommendation, however, will be covered by special report in the near future.)"

On account of the difficulty in obtaining Manganese rail during the war period, I have not made recommendation referred to in the last paragraph above, but will do so in the near future, as I think if possible we should use Manganese rail at such points.

Railroad L.

Question 1. Quantity of Frictionless Rail in use on the ——— Railroad, weight and mill at which rolled.

Answer. Five hundred and two (502) tons of 92-lb. Frictionless Rail rolled in April, 1914, by the Pennsylvania Steel Company.

Question 2. A statement of the results obtained from the use of Frictionless Rail; and an expression of opinion as to the advantages and distavantages.

Answer. The above tonnage of Frictionless Rail was applied in heavy curve line eastward track ——— to ———, ———, ———, and one curve on the ——— Line at ———.

The rail laid between ——— and ——— has practically all been removed. At ———, ———, the rail is still in service. The conditions in this location are not as severe as the conditions between ——— and ———, and a much longer life will be obtained from rail in this location.

The rail at ——— was removed in about sixteen months from the date it was laid. At this location, the slow freight train tonnage is very heavy and at the same time, a seven-degree curve carries eight inches of elevation on account of high-speed passenger trains. The rail did not prove satisfactory at all.

The rail on one curve on the ——— Line has proven satisfactory. However, this is a light tonnage location with a good number of high-speed passenger trains. The grade is descending and the super-elevation being favorable to the rail. The Frictionless Rail at this point has reduced the wear on the high rail.

The Frictionless Rail on descending grades (75 feet per mile) from ——— to ———, has given an average life of three years, as against an average life of two years on the low side of these curves with our Standard Open-Hearth Rail. We have had located in connection with the Frictionless Rail on curves in this district Manganese rail, on the high side. The wear on the high rail has been reduced to a minimum on account of the Manganese rail installation. The disadvantages of Frictionless Rail, in our opinion, are as follows:

(1) The change of gage necessary on account of the reduced size of the head.

(2) If it becomes necessary to change a Frictionless Rail to a standard type of rail, a change of gage is necessary, or vice versa.

(3) The Frictionless Rail has no value as a relaying rail for sidings or other locations and can only be disposed of from a scrap standpoint, on account of its head and the condition of the rail after being removed

from service locations. Therefore, the average life of three years, as obtained in connection with our line, will be the maximum life of the rail. With the standard rail installation on curved line, the high rail will average a life of two years and after this period can be changed to the low side of the curve and used as a Frictionless Rail; while the low rail can be placed in the high rail location, thereby securing two years additional life.

It is undoubtedly a fact that the Frictionless Rail saves curve wear on the high rail; furthermore, we are willing to admit that the rail which we received was somewhat soft and flowed very readily under the heavy wheel loads. It must be remembered, however, that we cannot take a chance with Frictionless Rail rolled with excessive high carbon. The head is very small, and, by so doing, we would undoubtedly experience trouble from broken rails. It is our opinion that Frictionless Rail will do good work where it is laid in track used exclusively for high-speed passenger service, or where all trains are operated at a reasonably high speed. It does not give satisfactory service where a reasonably high elevation must be maintained for fast trains; while at the same time a heavy tonnage of slow freights are also handled over the track.

Railroad M.

(1) In August, 1915, this Company purchased from the Illinois Steel Company about forty-five (45) tons of Frictionless companion to 90-lb. A. R. A. Type "A" rails.

(2) These rails were laid in six (6) degree curves on two per cent. grades. New standard section rails were laid opposite the Frictionless Rails. Other curves of same degree and in same locality were laid about the same time with new standard rails, both inside and outside.

The rails covered by these experiments have been closely measured at different times, and we find that there is practionally no difference in the wear of rails opposite the Frictionless Rails and those on the outside of curves opposite standard rails. The Frictionless Rails themselves, however, were soft and the metal mashed down. We do not, therefore, expect any appreciable results on the frictionless part of the curves, for the reason that the Frictionless Rails in their flattened condition present practically as much tread surface bearing to wheels as on the standard rails.

Railroad N.

We purchased 1,500 tons of this rail, 90-lb. A. R. A. Series "A" section, which was rolled by the Tennessee Coal, Iron & Railroad Company, in 1913, and was distributed over the various lines of our system, and installed mostly in the year 1914.

The ——— Company placed Frictionless Rail on curves varying from 6 degrees to 10 degrees on its various mountain divisions, where grade is heavy, and owing to single track, the speed variable. Trouble was experienced with "flow of metal," or, as the local men put it, "frazzled" condition. All of the Frictionless Rail on the ——— was condemned and ordered out of track toward the end of 1917, showing an average life of somewhat less than three years, against an average life of four or more years for standard 90-lb. section, in the same territory.

The results on the ——— Lines enforce similar conclusions. Here the traffic is lighter and the life of the Frictionless Rail, on some of the curves, has been about 4 to 6 years against approximately 6 years for standard rails. The experiment on these lines is not as yet complete, as they have not been condemned, as in the case of the ——— System.

Reports of our Division Officers failed to indicate any advantages derived from the use of this rail on the ——— Lines, except some conflicting opinion regarding reduced cost of maintenance.

Railroad O.

I have not complete information to give on the subject at the present moment, but, in order to meet your requirement of replying at an early date, I beg to advise that our operating people, such as the Superintendent and the Roadmaster, are not well impressed with this rail after having seen it in service on our curved track near ———, on the Eastern Division, for the past two years. We are taking out a great deal of it at the present time on account of the fact that it is so badly mashed and worn that it must be removed. Ordinary A. S. C. E. Section 85 and 90-lb rail, which was in on this track prior to the use of the Frictionless Rail, had an average life of four or five years. Our operating people have not found it possible to haul any greater tonnage over these curves with the Frictionless Rail than with the ordinary section. This is 90-lb. Frictionless Rail, and is the same rail mentioned in a report made under date of June 25, 1917, in connection with it. It is Section 9039, Illinois Steel Company, Open-Hearth rail, purchased in accordance with A. R. E. A. Specifications of March 17, 1915. There were 422 gross tons ordered February 29, 1916, which is the rail in question. It was placed on 6, 8 and 10-degree curves.

From the rather meager data at hand it is my opinion that there is no advantage to this rail, as I do not believe it will result in hauling any more tonnage around the curves, and it appears to wear out more rapidly than ordinary section rail.

I will give you a more complete report at a later date.

Railroad P.

We laid in the summer of 1916, 50 tons of Frictionless Rail, 90-lb., on the inside of six 8° curves on a hill averaging 1.6 per cent. grade. This hill, which is about two and one-half miles long, including three other 8° curves and a number not so sharp, were laid with A. R. A.-A. 90-lb. rail at the same time.

The traffic on this hill is six passenger trains averaging about four coaches each, about one-third of the cars steel, drawn by a modern Pacific type passenger engine of about 30,000 lbs. tractive power, and four passenger trains, two wooden coaches each, drawn by light American type, eight-wheel passenger engine, cylinder 18+24—speed, twenty to thirty-five miles per hour—passenger trains all daily. The freight traffic consists of approximately twelve freight trains daily, except Sunday, gross tonnage, exclusive of engine and caboose, probably averages 500 tons per train. Engines about equally divided between 60-ton and 95-ton consolidation, exclusive of tenders, which weigh 50 to 60 tons each. Speed of freight trains six to twenty miles per hour. Going up hill speed is slow, probably average eight miles per hour, so there is but little thrust on outside rail, but pretty heavy weight on inside rail.

All of the rail, both Standard and Frictionless, is standing up well, none showing any sign of mashing or other defects. The Frictionless is fringing just a little in places, not enough to offer criticism. It naturally must fringe some with heavy slow moving freight trains. The traffic is lead ore and coal principally—cars loaded to the limit.

The rail has not been laid long enough to judge intelligently whether or not the Frictionless type is worth while. So far, practically no difference in wear can be seen between the Standard and narrow-head rail. One of the claims most strongly advanced by the Frictionless people is that it prevents the cutting by flange of the outside rail. On this road, with comparatively light passenger traffic, though a speed of thirty-five miles per hour is about as fast as a train should run around an 8° curve, I have my doubts, owing to the slow moving freight trains, if the extra cost of the rail and increased labor is worth the difference. Perhaps on high speed lines, if it is true that the narrow head tends to lessen the wear of the outside rail, it may be of more advantage than the indications are that it will be here.

Frictionless Rail Data—Received in Reply to Questionnaire of August 3, 1917.

Road No.	(1)	(2)	(3)
Total tonnage Frictionless Rail	282.5	315	15.7
Typical Curve Data	1550′ 2° D. Trk.	1627′ 3° to 5°18′ S. Trk.	1058′ 4° D. Trk.
Grade	0.2% Adverse	....	.09%
Superelevation	1¾″	3″	2″
Locomotives:			
Pacific—Wgt. on drivers, Rgd. wh. base	....	....	....
10 Wheel—Wgt. on drivers, Rgd. wh. base	....	....	....
Consolidation—Wgt. on drivers, Rgd. wh. base	....	....	....
Mikado—Wgt. on drivers, Rgd. wh. base	218,300lb 16′-6″	239,900lb	233,500lb 16′-6″
Santa Fe—Wgt. on drivers, Rgd. wh. base	....	301,800lb	....
Mallet—Wgt. on drivers, Rgd. wh. base	....	....	....
Ave. Speed—Passenger	None	35 mph	None
Ave. Speed—Freight	15 mph.	20 mph.	10 mph.
Tonnage over Frictionless Rail—per Year	5,000,000	2,746,555	3,821,550
Gage, as laid. Before Frictionless	4′-8½″	4′-8½″	4 8½
Gage, as laid. With Frictionless	4′-8½″	4′-8 11/16″	4-8½
Cant of rail as laid	None	1 in 40	None
Rail Data:			
Before Frictionless—High Rail	85lb ASCE, TC&I, 1907, C-59-72*	90lb ARA A, Lack. 1910, C-62-75*	80lb ASCE, ISCo., 1913, C-56 ave.*
Before Frictionless—Low Rail	85lb ASCE, TC&I, 1907, C-59-72*	90lb ARA-A, Lack. 1910, C 62-75*	80lb ASCE, ISCo., 1913, C-56 ave.*
With Frictionless—High Rail	90lb ARA-A, TC&I, 1914, C-63-72†	90lb ARA-A, Gary, 1914	100lb, ISCo., 1915, C-56 ave.*
With Frictionless—Low Rail	90lb F, ISCo., 1914, C-64-70†	90lb F, Gary, 1914, C-.73‡	90lb F, ISCo., 1914, C-.68 ave.*
Results:			
1. Taking life of high rail, before installation of frictionless rail as low rail, as 100%, what in your judgment is the comparative life of high rail, since installing of frictionless mate, on this typical curve and on basis of same tonnage over rails?	175%	150%	100%
2. Same for low rail, taking life of low rail prior to use of frictionless rail, as 100%?	350%	100%	100%
3. Effect of frictionless rail on			
a Wear of high rail	Reduced 50%	Reduced 50%	None
b Wear of low rail	Reduced 50%	None	None
c Maintenance of line	None	None	None
d Maintenance of gage	Much easier to maintain	None	None
e Maintenance of surface	Much easier to maintain	None	None
f Maintenance of Joints, etc.	None	None	None
4.* What % saving in cost of mntce. of curves do you consider effected by use of Frictionless Rail?	50%	....	None
Remarks:	Wear on this curve reduced to equivalent wear on tangent		

*Chemical Composition from specifications.
†Chemical Composition from test ladle analysis.
‡Chemical Composition from analysis of rail.

Addressed to All Roads Having This Type of Rail in Service.

(4)	(5)	(6)	(7)
1792	500	350	500
660' 10° 6' S. Trk.	839^{84}' 10° S. Trk	2265' 8° S. Trk.	660' 7° S. Trk
2.025% Adverse	0.78%	1.6%	Nearly level
4½"	4½"		7"
	172.000lb 13'-4"		150,000lb 13' 0"
	160,000lb 13'-10"		
183,200lb 15'-6" 187,000lb 15'-8" 230,680lb 19'-9" 210,000lb 16' 0"	187.000lb 15'-8" 210,000lb 16'-6"		176,000lb 17'-0" 213,500lb 16'-6"
356,500lb 15'-6" 401,000lb 15'-0"	266,000lb 10'		
30 mph	30 mph	30 mph	About 40 mph
18 mph	18 mph	20 mph	About 20 mph
7,504,694			Over 6,000,000
4'-8⅞"	4'-9"	4-8½	4-8¾"
4'-8⅞"	4'-9"	4-8¾	4-8¾
	None	None	None
90lb ARA-A, ISCo., 1909, C-0.63-, .76* 90lb ARA-A, ISCo., 1909, C-0.63-, .76* 90lb ARA-A, ISCo., 1909, C-0.63-, .76* 90lb F, TC& I, 1913, C-0.68†	90lb CS, TC&I, 1907, C-.60* 90lb CS, Md., 1905, C-.60* 90lb CS, Md., 1905, C-.60* 90lb F, TC&I, 1913, C-.63-.76*	90lb ARA, ISCo., 1910, C- 90lb ARA, ISCo., 1910, C- 90lb ARA, ISCo., 1910, C- 90lb F, ISCo., 1912	85lb ASCE, Beth., 1909 85lb ASCE, Beth., 1909 85lb ASCE, Beth., 1910 See Remarks, Beth., 1911. C-.67-.80*
100%	101.7%	80%	240%
77%	86 8%	75%	Not less than 300%
None Excessive	Slightly less Considerably greater. Metal flows		Materially less Materially less
None Tendency to roll out increased None More adzing of Ties	None None None None	None None None None	Materially less Materially less
None	None	None	More than 50%
Rail failures have been straight breaks with no previous indication of approaching failure visible.... Joint A. T. & S. F. Ry. and S. P. traffic over this track.		Frictionless rail not a success. Does not compare with ARA by 25%. Flows very badly. Wears in spots after being laid one year	The frictionless rails were made by planing 85lb ASCE sections rail. Decrease in tendency to roll out. Little adzing of ties and regaging compared to large amount previously with standard sections.

Frictionless Rail Data—Received in Reply to Questionnaire of August 3, 1917,

Road No.	(8)	(9)	(10)
Total tonnage Frictionless Rail	26	20	
Typical Curve Data	760′ 10° D.Trk.	386′ 17° S.Trk.	481′ Rad 261′ 4 Trk.
Grade	2%	2½%	Level
Superelevation	1½″	3″	3″
Locomotives:	All types used by 22 railroads		40 Ton. Electric Motor Cars
Pacific—Wgt. on drivers, Rgd. wh. base			
10 Wheel—Wgt. on drivers, Rgd. wh. base			
Consolidation—Wgt. on drivers, Rgd. wh. base		208,000lb 16′	
Mikado—Wgt. on drivers, Rgd. wh. base			
Santa Fe—Wgt. on drivers, Rgd. wh. base			
Mallet—Wgt. on drivers, Rgd. wh. base			
Ave. Speed—Passenger	15 mph	12 mph	10 mph
Ave. Speed—Freight	15 mph	12 mph	
Tonnage over Frictionless rail—per Year	Very large tonnage	1,500,000	13,000,000
Gage, as laid. Before Frictionless		4′-9″	4-8¾
Gage, as laid. With Frictionless		4′-9″	4-8¾
Cant of rail as laid	1°30′		
Rail Data:			
Before Frictionless—High Rail	100lb ASCE	90lb ASCE, Beth., 1913, C-.654†	80lb ASCE, ISCo., C-.75†
Before Frictionless—Low Rail	100lb ASCE	90lb ASCE, Beth., 1913, C-.654†	80lb ASCE, ISCo., C-.75†
With Frictionless—High Rail	100lb ASCE	90lb ASCE, Beth., 1913, C-.654†	80lb ASCE, Beth., 1916, C-.75†
With Frictionless—Low Rail	100lbF	97lbF, Beth., 1915, C-.626†	79½F, Beth., 1916, C-.852
Results:			
1. Taking life of high rail, before installation of frictionless rail as low rail, as 100%, what in your judgment is the comparative life of high rail, since installing of frictionless mate, on this typical curve and on basis of same tonnage over rails?	115%	150%	
2. Same for low rail, taking life of low rail prior to use of frictionless rail, as 100%?	200%	150%	
3. Effect of frictionless rail on			
a Wear of high rail	Wears less		
b Wear of low rail	Wears less		
c Maintenance of line	Less Mntce.		
d Maintenance of gage	Less Mntce.		
e Maintenance of surface	Less Mntce.		
f Maintenance of Joints, etc	Less Mntce.		
4. What % saving in cost of Mntce. of curves do you consider effected by use of Frictionless rail?	Considerable	Unable to estimate.	
Remarks:	On steel viaduct	Believe frictionless rail of .70-.75 carbon would give excellent results	Not in long enough to make report.

*Chemical Composition from specifications.
†Chemical Composition from test ladle analysis.
‡Chemical Composition from analysis of rail

Addressed to All Roads Having This Type of Rail in Service.—Continued.

(11)	(12)	(13)	(14)
			200
208' Rad 100' D.Trk.	8°		977'3°40' to 2806'6°. S.Trk.
½%	1.6%		0.5% to 1.10%
3"			
Electric Motor Cars, 38 ton ld.			
			140,000lb 13'-0"
			198,000lb 16'-6"
10 mph			40 mph
None			25 mph
15,000,000			3,750,000
			4'-⅝" for 4°C 4'8¾" for 5°&6°
			4'-8⅝" for 4°C 4'8¾" for 5°&6°
			1°26' (1 in 40)
85lb ASCE, Beth., 1911, C.838‡			
85lb ASCE, Beth., 1911, C.803‡			
85lb, ASCE, Beth., 1916, C.87‡			85lb, CPR, Algoma, 1914, C-.58-.72*
79½ F, ASCE, 1912, C.914‡			87.75lbF, Algoma, 1915, C-.555 head ‡.
110%			
110%			
Wears more even			
Wears more even			
None			
None			
None			
None			
.10%			
Cars pass over curve much easier since Frictionless was installed. A guard rail is attached to inner rail to prevent derailments from any cause. Its use not discontinued to obtain ultimate results from Frictionless rail. Results entirely satisfactory and use being extended.	Rail not in use long enough for definite report.	Seem to get good results where high speed is used. Not nearly so good with slow speed or where engines usually stop. In general frictionless rail has flowed to inside of rail from $\frac{1}{16}$" to ¼" and to outside of rail from $\frac{1}{16}$" to ¾".	Rail proved too soft to maintain narrow running surface desired. A decided decrease in flange wear on outer rail indicated. Still more satisfactory results would no doubt have been obtained had Frictionless rail been sufficiently hard to maintain its section.

REPORT OF COMMITTEE XV—ON IRON AND STEEL STRUCTURES.

O. E. Selby, *Chairman;*
F. Auryansen,
J. A. Bohland,
W. S. Bouton,
A. W. Carpenter,
Charles Chandler,
J. E. Crawford,
F. O. Dufour,
W. R. Edwards,
A. Chas. Irwin,
B. R. Leffler,
W. H. Moore,
P. B. Motley,
C. D. Purdon,

F. E. Turneaure, *Vice-Chairman;*
Albert Reichmann,
J. W. Reid,
A. F. Robinson,
H. N. Rodenbaugh,
H. B. Seaman,
C. E. Smith,
I. F. Stern,
H. B. Stuart,
G. E. Tebbetts,
L. F. VanHagan,
J. A. L. Waddell,
H. T. Welty,

Committee.

To the American Railway Engineering Association:

Your Committee on Iron and Steel Structures respectfully submits its annual report to the Association.

The subjects assigned to the Committee by the Board of Direction are:

1. Make critical examination of the subject-matter in the Manual, and submit definite recommendations for changes:
   (a) Revise the General Specifications for Steel Railway Bridges.
   (b) Revise the rules and unit stresses for classifying and rating the capacity of existing bridges.

2. Methods of protection of iron and steel structures against corrosion.

Report upon the use of plastic compounds for the protection of steel work exposed to the blast action from locomotive stacks.

3. Relative economy of various types of movable bridges.

Revise the Specifications for Movable Bridges and report them for adoption.

4. Secondary stresses and impact.
   (a) Report definite principles for design to reduce secondary stresses and rules for computing or allowing for them.
   (b) Study and draw conclusions from records of impact tests.
   (c) Continue impact tests and stress measurements as funds may be available.

5. Report on column tests.

Continue with program of column tests as far as the work of the Bureau of Standards will permit.

6. Report on design, length and operation of turntables.
   (a) Report specifications for the design of turntables and turntable pits.

(b) Report specifications for metal for turntable roller and disc bearings.

7. Report on ballast floor bridges and methods in use for waterproofing.

Report on principles for detailed design of flashing, drainage and reinforcement for waterproofing purposes.

8. Report on track scale superstructures, collaborating with Committee on Yards and Terminals.

COMMITTEE MEETINGS.

Since the 1918 convention the following meetings of the Committee and Sub-Committees have been held:

Committee, Chicago, June 11, 1918.
Committee, Cleveland, December 18 and 19, 1918.
Sub-Committee No. 1, Chicago, August 8, 1918.
Sub-Committees 1 and 4 joint, Cincinnati, November 12 and 13, 1918.
Sub-Committees 1 and 4 joint, Philadelphia, December 5 and 6, 1918.

As usual, the subjects assigned to the Committee were assigned to Sub-Committees, and the reports of the Sub-Committees were considered at a meeting of the whole Committee.

To Sub-Committee No. 1 was assigned Subject No. 1 (a), Revise the General Specifications for Steel Railway Bridges, and to Sub-Committee No. 4 was assigned Subject No. 4, Secondary Stresses and Impact. The work of this Sub-Committee during the past year has been entirely in connection with the revision of the specifications so far as it concerned the matters of unit stresses, impact, and secondary stresses. The two joint meetings of Sub-Committees Nos. 1 and 4, and the meeting of the Committee at Cleveland were devoted entirely to a detailed discussion of the revision of the specifications for steel railway bridges. It will thus be seen that a total of six days of consideration have been given by substantial representation of the Committee to the revision of the specifications.

(1) REVISION OF MANUAL.

(a) Revise the General Specifications for Steel Railway Bridges.

The Association's General Specifications for Steel Railway Bridges were adopted in 1906, and are printed in the Manual, pp. 482 to 505, inclusive. The Specifications for Erection were adopted in 1912 and are printed in the Manual, pp. 508 to 513, inclusive.

The revised specifications (Appendix A to this report) are submitted by your Committee as a conclusion, to be printed in the Manual in place of the specifications referred to above.

(b) Revise the Rules and Unit Stresses for Classifying and Rating the Capacity of Existing Bridges.

These rules are given in the Manual, pp. 506 and 507. The Committee is not ready to report any changes, but expects to be able to report at the next convention revised rules for rating based upon the live load diagram used in the specifications and with details of unit stresses, impact, etc. The Committee invites suggestions from the members of the Association and others on this subject.

(2) METHODS OF PROTECTION OF IRON AND STEEL STRUCTURES AGAINST CORROSION.

The Committee has under observation some experimental applications of plastic compounds for the protection of structures of steel and concrete exposed to direct action of the blast from locomotive stacks, but has no report to make to this convention.

(3) RELATIVE ECONOMY OF VARIOUS TYPES OF MOVABLE BRIDGES.

Specifications for Movable Bridges were submitted to the 1918 convention and printed in the Proceedings, Vol. 19, pp. 814 to 866, inclusive. The Committee is engaged in a revision of these specifications and expects to submit them to the 1920 convention for adoption and printing in the Manual. The Committee invites suggestions and criticisms of these specifications for movable bridges in order that the revision, when submitted to the convention, may be as satisfactory as possible.

(4) SECONDARY STRESSES AND IMPACT.

The conclusions of the Committee with reference to secondary stresses are embodied in the specifications. No experimental work on impact has been done during the past year and none is contemplated. The conclusions from the experimental work already done have been presented to the Association from time to time, and the Association has adopted an impact formula based upon them. The conclusions already reached have been based upon a large amount of experimental work, and are not likely to be modified by any further work of that kind which the Committee might be able to do in the near future. The Sub-Committee on this subject has been discharged, effective with the presentation of this report to the convention, and the Committee requests that this subject be discontinued by the Board of Direction.

(5) REPORT ON COLUMN TESTS.

On account of war conditions the Committee has been unable to make any further tests on columns, and the Committee requests the Board of Direction to continue the subject in order that further study may be made when the conditions will allow it.

(6) REPORT ON DESIGN, LENGTH AND OPERATION OF TURNTABLES.

(a) Report Specifications for the Design of Turntables and Turntable Pits.

(b) Report Specifications for Metal for Turntable Roller and Disc Bearings.

The Committee requests that Subject (a) be continued by the Board of Direction, and that Subject (b) be dropped.

(7) REPORT ON BALLAST FLOOR BRIDGES AND METHODS IN USE FOR WATERPROOFING.

A report on the principles for detailed design of flashing, drainage and reinforcement for waterproofing purposes is being worked upon by the Sub-Committee and is expected to be ready to present to the convention with the report of 1920.

(8) REPORT ON TRACK SCALE SUPERSTRUCTURES, COLLABORATING WITH COMMITTEE ON YARDS AND TERMINALS.

In the report of the Committee on Yards and Terminals to the 1918 convention (Proceedings, Vol. 19, p. 323) the Committee on Iron and Steel Structures was asked to approve the data of scale superstructures contained in Tables 1 and 2 on pp. 330 and 331 of the Proceedings, Vol. 19. These tables contain the data for designing and the resultant recommended girder section for weigh-bridge girders and transverse floor beams for track scales of three different standard sectional capacities.

After conference with the Yards and Terminals Committee and careful study of the sections proposed, the Committee approves the recommended sections.

RECOMMENDATIONS.

The Committee recommends that the following action be taken on its report:

1. That the conclusion under Subject No. 1, Revision of the General Specifications for Steel Railway Bridges, be adopted and the Specifications, Appendix A, printed in the Manual.

2. That the approval of the sections for track scales, weigh-bridge girders, and transverse floor beams recommended by the Committee on Yards and Terminals be recorded in the Proceedings.

Respectfully submitted,

Committee on Yards and Terminals.

Appendix A.

GENERAL SPECIFICATIONS FOR STEEL RAILWAY BRIDGES

For Fixed Spans Less Than 300 Feet in Length.

1919

(1) PROPOSALS AND DRAWINGS.

Definitions of Terms.

1. The term "Engineer" refers to the Chief Engineer of the Company or his subordinates in authority. The term "Inspector" refers to the inspector or inspectors representing the Company. The term "Company" refers to the Railway Company or Railroad Company party to the contract. The term "Contractor" refers to the manufacturing or fabricating contractor party to the contract. The term "Erector" refers to the erecting contractor party to the contract.

Proposals.

2. Bidders shall submit proposals to conform with the terms in the letter of invitation. The proposals preferably shall be based upon plans and specifications furnished by the Company showing the general dimensions necessary for designing the structure, the stresses and the general or typical details. Invitations covering work to be erected by the Contractor shall state the general conditions at the site, such as character of foundations, traffic conditions, etc.

Drawings to Govern.

3. Where the drawings and the specifications differ, the drawings shall govern.

Patented Devices.

4. The Contractor shall protect the Company against claims on account of patented devices or parts.

Drawings.

5. After the contract has been awarded and before any shop work is commenced, the Contractor shall submit to the Engineer for approval duplicate prints of stress sheets and shop drawings, unless such drawings shall have been prepared by the Company. The tracings of these drawings shall be the property of and be delivered to the Company after the completion of the contract. Shop drawings shall be made on the dull side of the tracing cloth, 24 by 36 inches in size, including margins. The margin at the left end shall be 1½ inches wide, and the others ½-inch. The title shall be in the lower right-hand corner. No changes shall be made on any approved drawing without the consent, in writing, of the Engineer.

6. The Contractor shall be responsible for the correctness of his drawings, and for shop fits and field connections, although the drawings may have been approved by the Engineer.

7. Any material ordered by the Contractor prior to the approval of the drawings shall be at his risk.

(2) GENERAL FEATURES OF DESIGN.

Materials Used.

8. Structures shall be made wholly of structural steel except where otherwise specified. Cast steel may be used for shoes and bearings. Cast iron may be used only where specifically authorized by the Engineer.

Types of Bridges.

9. The different types of bridges may be used as follows:

Rolled beams for spans up to 35 feet.
Plate girders for spans from 30 feet to 125 feet.
Riveted trusses for spans from 100 feet to 300 feet.
Pin-connected trusses for spans from 150 feet to 300 feet.

Number of Trusses.

10. Unless otherwise specified, double-track through bridges shall have only two trusses or girders, and four-track bridges three.

Dimensions for Calculation.

11. The dimensions for the calculation of stresses shall be as follows:

SPAN LENGTH.

For trusses and girders, the distance center to center of end bearings.

For floor beams, the distance center to center of trusses or girders.

For stringers, the distance center to center of floor beams.

DEPTH.

For riveted trusses, the distance between centers of gravity of chord sections.

For pin-connected trusses, the distance center to center of chord pins.

For plate girders, floor beams and stringers, the distance between centers of gravity of flanges, but not to exceed the distance back to back of the flange angles.

Spacing of Trusses, Girders and Floorbeams.

12. The width center to center of girders or trusses shall be not less than one-twentieth of the effective span, and not less than is necessary to prevent overturning under the assumed lateral loading. Panel lengths shall not exceed 1½ times the width c. to c. of trusses or girders.

General Features of Design—Loads.

Clearances.

13. If the alinement is straight, clearances shall be not less than shown on the diagram, Fig. 1. If the alinement is curved, the width of the diagram shall be increased so as to provide the same minimum clearances for a car 80 feet long, 14 feet high and 60 feet center to center of trucks, allowance being made for curvature and superelevation of rails. The height of rail shall be assumed as 6 inches.

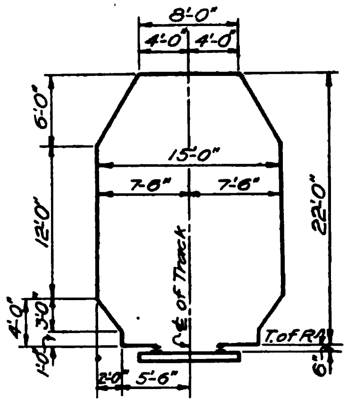


Fig. 1.

Deck Spans on Curves.

14. Deck spans on curves shall have the center line of the span placed, usually, so as to bisect the middle ordinate of and be parallel with the chord of the curve.

Skew Bridges.

15. In skew bridges without ballasted floors, the backwalls for each track shall be square with the track.

Ambiguity of Stress.

16. Structures shall be designed so as to avoid, as far as practicable, ambiguity in the determination of the stresses.

(3) LOADS.

Loads.

17. The structures shall be proportioned for the following loads:

a. The dead load.
b. The live load.
c. The lateral load.

Stresses due to these loads, as hereinafter specified, shall be shown separately on the stress sheets.

18. Members shall be proportioned for that combination of stresses which gives the maximum total stress, except as otherwise provided.

Dead Load.

19. The dead load shall consist of the estimated weight of the entire suspended structure. Timber shall be assumed to weigh 4½ pounds per foot B. M., ballast 120 pounds per cubic foot, reinforced concrete 150 pounds per cubic foot, waterproofing 150 pounds per cubic foot, and rails and fastenings 150 pounds per linear foot of track. If ballast is used, it shall be assumed level with the base of rail and the weight of ties neglected.

Loads.

Live Load.

20. The minimum live load for each track shall be as shown in Figs. 2 and 3.

The loading that gives the larger stresses shall be used.

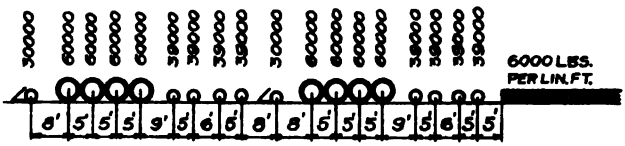


FIG. 2.

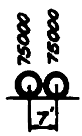


FIG. 3.

Heavier Loading.

21. Heavier loadings shall be proportional to the specified minimum loadings with the same wheel spacing.

22. In calculating the maximum stresses due to live load and centrifugal force when two, three or four tracks are simultaneously loaded, use the following percentages of the specified live load:

For two tracks loaded, 95 per cent.
For three tracks loaded, 90 per cent.
For four tracks loaded, 85 per cent.

Floors.

23. Wooden ties shall be designed for the maximum wheel load specified distributed over three ties and with 100 per cent. impact added. The fiber stress shall not exceed 2,000 pounds per square inch. Wooden tie floors shall be secured to the stringers or girders. The ties shall be not less than 10 feet in length. They shall be placed with openings not to exceed 4 inches in width and shall be secured against bunching. The maximum dap of ties shall be 1½ inches.

24. Floors consisting of beams transverse to the axis of the structure shall be designed for a uniform live load of 15,000 pounds per linear foot for each track, when the minimum live load specified is used. When heavier loadings are used, this uniform load shall be increased proportionately. Floors consisting of longitudinal beams shall be designed for the wheel loads specified.

25. In ballasted floor bridges, the live load shall be considered as uniformly distributed laterally over a width of 10 feet.

26. Ballasted floors shall have at least 6 inches of ballast under the ties.

Reduced Dead Load for Solid Floors.

27. In bridges with ballasted floors, only three-fourths of the computed dead weight of the floors shall be considered.

Loads.

Impact.

28. The dynamic increment of the live load shall be added to the maximum computed live load stresses and shall be determined by the formula,

$$I = S \frac{300}{300 + \frac{L^2}{100}}, \text{ in which}$$

I = impact or dynamic increment to be added to the live-load stress.
S = computed maximum live-load stress.
L = the following values in feet:

a. For spans, the distance center to center of end bearings.
b. For stringers, the distance center to center of floor beams.
c. For hip verticals and similar suspenders, floor beams, and transverse girders and their supports, the sum of the adjacent panel or span lengths.
d. For floors with transverse beams, zero.

29. For bridges designed exclusively for electric locomotives, the impact stresses shall be taken as one-half of those given by the formula in paragraph 28.

30. Impact shall not be added to stresses produced by longitudinal or lateral forces.

Eccentricity of Load on Curves.

31. For bridges on curves, provision shall be made for the increased load carried by any truss, girder or stringer due to the eccentricity of the load.

Lateral Forces.

32. The lateral force shall consist of a moving load equal to 30 pounds per square foot on 1½ times the vertical projection of the structure on a plane parallel with its axis (but never less than 200 pounds per linear foot at the loaded chord, and 150 pounds per linear foot at the unloaded chord), and a moving load of 600 pounds per linear foot applied 8 feet above the base of rail.

33. In calculating the stresses in viaduct towers due to lateral force, the viaduct shall be considered as loaded on either one or both tracks, with empty cars weighing 1,200 pounds per linear foot.

34. If a moving load of 50 pounds per square foot on 1½ times the vertical projection of the unloaded structure on a plane parallel with its axis produces greater stresses than the lateral force defined in paragraph 32, it shall be provided for.

35. The bracing between chords or flanges shall be capable of resisting a transverse shear in any panel equal to 2 per cent. of the total axial stress in the two chords in that panel.

Centrifugal Force.

36. On curves, the centrifugal force (assumed to act 6 feet above

the rail) shall be taken equal to a percentage of the live load according to the following table:

Degree of Curve	0° 20′	0° 40′	1°	2°	3°	4°	5°	6°	7°	8°	9°	10°	11°	12°
Percentage of live load	2½	5	7½	10	10	10	10	10	10	10	10	10	10	10
Speed in miles per hour	80	80	80	65	53	46	41	38	35	33	31	29	28	27

Longitudinal Force.

37. Provision shall be made in the design for the effect of a longitudinal force of 20 per cent. of the live load on one track only, applied 6 feet above the top of the rail. Where, by reason of continuity of members or frictional resistance, the longitudinal force will be largely absorbed before it reaches supporting members, its effect on such members shall be taken as one-half that specified above.

Applications of Live Load.

38. The stresses shall be shown for the following applications of the live load:

a. As a dynamic load acting vertically, the static stresses and the dynamic increments or impact stresses being shown separately and designated as the live-load static stresses and the live-load impact stresses respectively.

b. As a static longitudinal force, due to tractive effort or braking, the stresses being designated as longitudinal force stresses.

c. As a lateral force on curves, the stresses being shown separately for this force acting as a static load and designated as the centrifugal force stresses.

(4) UNIT STRESSES AND PROPORTIONING OF PARTS.

39. The several parts of structures shall be so proportioned that the unit stresses will not exceed the following, except as modified in paragraphs 47 and 48:

	Pounds per sq. inch
Axial tension, net section	16,000
Axial compression, gross section	$13{,}000 - \frac{1}{4}\left(\frac{l}{r}\right)^2$
l = the length of the member in inches.	
r = the least radius of gyration of the member in inches.	
Tension in extreme fibers of rolled shapes, built sections and girders, net section	16,000
Tension in extreme fibers of pins	24,000
Shear in plate girder webs, gross section	10,000

Unit Stresses and Proportioning of Parts.

Shear in power-driven rivets and pins..12,000
Bearing on power-driven rivets, pins, outstanding legs of stiffner angles, and other steel parts in contact....24,000

The above mentioned values for shear and bearing shall be reduced 25 per cent. for countersunk rivets, hand-driven rivets, floor-connection rivets, and turned bolts.

Bearing on expansion rollers, per linear inch.........600*d*
d = the diameter of rollers in inches.

	Pounds per sq. inch
Bearing on granite masonry........................	800
Bearing on sandstone and limestone masonry........	400
Bearing on concrete masonry........................	600

40. For cast steel in shoes and bearings, the above mentioned unit stresses shall apply.

41. The diagonal tension in webs of girders and rolled beams at sections where maximum shear and bending occur simultaneously, shall not exceed 16,000 pounds per square inch.

Effective Bearing Area.

42. The effective bearing area of a pin, a bolt or a rivet shall be its diameter multiplied by the thickness of the piece, except that for countersunk rivets half the depth of the countersink shall be omitted.

Effective Diameter of Rivets.

43. In proportioning rivets, the nominal diameter of the rivet shall be used.

Reversal of Stress.

44. Members subject to reversal of stress under the passage of the live load shall be proportioned as follows:

Determine the resultant tensile stress and the resultant compressive stress and increase each by 50 per cent. of the smaller; then proportion the member so that it will be capable of resisting either increased resultant stress. The connections shall be proportioned for the sum of the resultant stresses.

Stresses in Web Members.

45. In proportioning web members of trusses, use two-thirds of the dead load stress plus one and one-sixth times the live load stress, including impact, where this sum is greater than the sum of the deal load stress and the live load stress, including impact.

Combined Stresses.

46. Members subject to both axial and bending stresses (including bending due to floor beam deflection) shall be proportioned so that the combined fiber stresses will not exceed the allowed axial stress. In members continuous over panel points, only three-fourths of the bend-

ing stress computed as for simple beams shall be added to the axial stress.

47. Members subject to stresses produced by a combination of dead load, live load, impact and centrifugal force, with either lateral or longitudinal forces, or bending due to lateral action, may be proportioned for unit stresses 25 per cent. greater than those specified in paragraph 39; but the section shall not be less than that required for dead load, live load, impact and centrifugal force.

Secondary Stresses.

48. Designing and detailing shall be done so as to avoid secondary stresses as far as possible. In ordinary trusses without subpanelling, no account usually need be taken of the secondary stresses in any member whose width measured in the plane of the truss is less than one-tenth of its length. Where this ratio is exceeded, or where subpanelling is used, secondary stresses due to deflection of the truss shall be computed. The specified unit stresses may be increased one-third for a combination of the secondary stresses with the axial stresses.

Compression Flanges.

49. The gross area of the compression flanges of plate girders shall not be less than the gross area of the tension flanges, but the stress per square inch shall not exceed

$$14{,}000 - 200\frac{l}{b}, \text{ in which}$$

l = the length of the unsupported flange, between lateral connections or knee braces.
b = the flange width.

(5) DETAILS OF DESIGN.

Limiting Lengths of Members.

50. The ratio of length to least radius of gyration shall not exceed 100 for main compression members nor 120 for wind and sway bracing.

51. The lengths of riveted tension members shall not exceed 200 times their least radius of gyration.

Depth Ratios.

52. The depth of trusses preferably shall be not less than one-tenth of the span. The depth of plate girders preferably shall be not less than one-twelfth of the span. The depth of rolled beams used as girders and the depth of solid floors preferably shall be not less than one-fifteenth of the span.

Parts Accessible.

53. Details shall be designed so that all parts will be accessible for inspection, cleaning and painting. Closed sections shall be avoided wherever possible.

Details of Design.

Pockets.

54. Pockets or depressions which would hold water shall have efficient drain holes, or shall be filled with concrete.

Eccentric Connections.

55. Members shall be connected so that their gravity axes will intersect in a point. Eccentric connections shall be avoided if practicable, but, if unavoidable, the members shall be proportioned to resist the additional stresses so produced.

Counters.

56. Riveted counters are preferred. If counters are subject to reversal of stress, their end connections preferably shall be riveted. Adjustable counters shall have open turnbuckles.

Strength of Connections.

57. Connections shall have a strength at least equal to that of the members connected, regardless of the computed stress. Connections shall be made, as nearly as practicable, symmetrical about the axis of the members.

Limiting Thickness of Metal.

58. Metal shall not be less than ⅜-inch thick, except for fillers. Metal subject to marked corrosive influences shall be increased in thickness or protected against such influences.

Effective Area of Angles.

59. The effective area of single angles in tension shall be assumed as the net area of the connected leg plus 50 per cent. of the area of the unconnected leg. The effective area of double angle members connected by both legs shall be assumed as 90 per cent. of the net area of the angles. Single angles connected by lug angles shall be considered as connected by one leg.

Sizes of Rivets.

60. Rivets shall be ⅞-inch in diameter unless otherwise specified.

Pitch of Rivets.

61. The minimum distance between centers of rivet holes shall be three diameters of the rivet, but the distance preferably shall be not less than 3½ inches for 1 inch rivets, 3 inches for ⅞-inch rivets and 2½ inches for ¾-inch rivets. The maximum pitch in the line of stress for members composed of plates and shapes shall be 7 inches for 1 inch rivets, 6 inches for ⅞-inch rivets and 5 inches for ¾-inch rivets. For angles with two gage lines and rivets staggered, the maximum pitch in each line shall be twice the amounts given above. If two or more web plates are used in contact, stitch rivets 12 inches in gage and pitch shall be provided to make them act in unison. In tension members composed of two angles in contact, a pitch of 12 inches may be used for riveting the angles together.

Details of Design.

Edge Distance.

62. The minimum distance from the center of any rivet hole to a sheared edge shall be: 1¾ inches for 1 inch rivets, 1½ inches for ⅞-inch rivets and 1¼ inches for ¾-inch rivets; to a rolled edge 1½ inches, 1¼ inches and 1⅛ inches, respectively. The maximum distance from any edge shall be eight times the thickness of the plate, but shall not exceed 6 inches.

Size of Rivets in Angles.

63. The diameter of the rivets in any angle whose size is determined by calculated stress shall not exceed one-fourth of the width of the leg in which they are driven. In angles whose size is not so determined 1 inch rivets may be used in 3½ inch legs, ⅞-inch rivets in 3 inch legs, and ¾-inch rivets in 2½ inch legs.

Long Rivets.

64. Rivets which carry calculated stress and whose grip exceeds four diameters shall be increased in number at least one per cent. for each additional 1/16-inch of grip. If the grip exceeds six times the diameter of the rivet, specially designed rivets shall be used.

Pitch of Rivets at Ends.

65. The pitch of rivets at the ends of built compression members shall not exceed four diameters of the rivet for a distance equal to one and one-half times the maximum width of the member.

Compression Members.

66. In built compression members, the metal shall be concentrated in the webs and flanges. The thickness of each web shall be not less than one-thirtieth of the distance between the lines of rivets connecting it to the flanges. The thickness of cover plates shall be not less than one-fortieth of the distance between the nearest rivet lines.

Outstanding Legs of Angles.

67. The width of the outstanding legs of angles in compression (except when reinforced by plates) shall not exceed the following:

a. For stringer flange angles, ten times the thickness.

b. For main members carrying axial stress, twelve times the thickness.

c. For bracing and other secondary members, fourteen times the thickness.

Stay Plates.

68. The open sides of compression members shall be provided with lacing bars and shall have stay plates as near each end as practicable. Stay plates shall be provided at intermediate points where the lacing is interrupted. In main members, the length of the stay plates shall be not less than 1¼ times the distance between the nearest lines of rivets connecting them to the flanges, and the length of intermediate stay plates

Details of Design.

shall be not less than three-quarters of that distance. Their thickness shall be not less than one-fiftieth of the same distance.

69. Tension members composed of shapes shall have their separate segments stayed together. The stay plates shall have a length not less than two-thirds of the lengths specified for stay plates on compression members.

Lacing.

70. The lacing of compression members shall be proportioned to resist a shearing stress of 2 per cent. of the direct stress. The minimum width of lacing bars shall be 3 inches for 1 inch rivets, 2¾ inches for ⅞-inch rivets, 2½ inches for ¾-inch rivets, and 2 inches for ⅝-inch rivets. The thickness shall be made as required by paragraph 39, in which "l" shall be taken as the distance between connections to the main sections.

71. In members composed of side segments and a cover plate, with the open side laced, one-half the shear shall be considered as taken by the lacing. Where double lacing is used, the shear in the plane of the lacing shall be equally distributed between the two systems.

72. In connecting lacing bars to flanges, ⅝-inch rivets shall be used for flanges less than 2½ inches wide, ¾-inch rivets for flanges from 2½ to 3½ inches wide, and ⅞-inch rivets for flanges 3½ or more inches wide. Lacing bars with at least two rivets in each end shall be used for flanges over 5 inches wide.

73. The angle of lacing bars with the axis of the member shall be not less than 45 degrees for double lacing, and 60 degrees for single lacing. If the distance between rivet lines in the flanges is more than 15 inches and a single rivet bar is used, the lacing shall be double and riveted at the intersections.

74. Lacing bars shall be so spaced that the $\frac{l}{r}$ of the portion of the flange included between their connections will be not greater than 40.

Splices.

75. Abutting joints in compression members faced for bearing shall be spliced on four sides. The gross area of the splice material shall be not less than 50 per cent. of the gross area of the member.

76. Joints in riveted work not faced for bearing, whether in tension or compression, shall be fully spliced.

Net Section at Pins.

77. In riveted tension members in pin-connected trusses, the net section across the pin hole shall be 135 per cent. and the net section back of the pin hole 100 per cent. of the net section of the body of the member, and there shall be sufficient rivets to make the material effective.

Details of Design.

Net Section Defined.

78. The net section of riveted members shall be the least area which can be obtained by deducting from the gross sectional area the areas of holes cut by any plane perpendicular to the axis of the member and parts of the areas of other holes on one side of the plane within a distance of four inches, which are on gage lines one inch or more from those of the holes cut by the plane, the parts being determined by the formula:

$$A\left(1-\frac{P}{4}\right), \text{ in which}$$

A = the area of the hole.
P = the distance in inches of the center of the hole from the plane.

79. In determining the net section, the diameter of the rivet hole shall be taken one-eighth-inch larger than the nominal diameter of the rivet.

Pin Plates.

80. Where necessary to give the required section or bearing area, pin holes shall be reinforced on both sides of each segment by plates, one of which on each side must be as wide as the outstanding flanges will permit. These plates shall contain enough rivets to transmit and distribute the bearing pressure uniformly over the full cross section. At least one full-width plate on each segment shall extend to the far edge of the stay plate and the others not less than 6 inches beyond the near edge.

Indirect Splices.

81. If splice plates are not in direct contact with the parts which they connect, rivets shall be used on each side of the joint in excess of the number required in the case of direct contact to the extent of two extra lines for each intervening plate.

Fillers.

82. Where rivets carrying stress pass through fillers, the fillers shall be extended beyond the connected member and the extension secured by additional rivets sufficient to develop the value of the filler.

Forked Ends.

83. Forked ends on compression members will be permitted only where unavoidable. Where forked ends are used, a sufficient number of pin plates shall be provided to make the jaws of twice the sectional area of the member and they shall be extended as far as necessary in order to carry the stress of the main member into the jaws, but shall not be shorter than required by paragraph 80.

Pins.

84. Pins shall be long enough to secure a full bearing of all parts connected upon the turned body of the pin. They shall be secured by chambered nuts or be provided with washers if solid nuts are used. The screw ends shall be long enough to admit of burring the threads.

Details of Design.

85. Pin connected members shall be held against lateral movement on the pins.

Bolts.

86. Where members are connected by bolts, the turned bodies of the bolts shall be long enough to extend through the metal. A washer at least ¼-inch thick shall be used under the nut. Bolts shall not be used except by special permission.

Upset Ends.

87. Bars with screw ends shall be upset so that the area at the root of the thread will be at least 15 per cent. larger than in the body of the bar.

Sleeve Nuts.

88. Sleeve nuts shall not be used.

Expansion.

89. Provision shall be made for expansion and contraction at the rate of one inch for every 100 feet in length. The expansion ends shall be secured against lateral movement. In spans over 250 feet in length, provision shall be made for expansion in the floor.

Expansion Bearings.

90. Spans 70 feet or more in length shall have turned rollers or rockers at one end. Spans of less length shall be arranged to slide on smooth surfaces. Expansion bearings shall be designed to permit longitudinal motion only.

Fixed Bearings.

91. Fixed bearings shall be firmly anchored to the supports.

Rollers.

92. Expansion rollers shall be not less than 6 inches in diameter. They shall be coupled together with substantial side bars, which shall be so arranged that the rollers can be cleaned readily. Rollers shall be geared to the upper and lower plates.

Pedestals and Shoes.

93. Pedestals and shoes shall be made of plates and angles, or cast steel. The difference between the top and bottom bearing widths shall not exceed twice the depth. For hinged bearings, the depth shall be measured from the center of the pin. The web plates and the angles connecting them to the base plate shall be not less than ¾-inch thick. If the size of the pedestal permits, the webs shall be rigidly connected transversely. The minimum thickness of the metal in cast steel pedestals shall be one inch. Pedestals and shoes shall be so constructed that the load will be distributed uniformly over the entire bearing. Spans 70 feet or more in length shall have hinged bearings at each end.

Inclined Bearings.

94. For spans on an inclined grade and without hinged bearings,

the sole or masonry plates shall be beveled so that the masonry surfaces will be level.

Name Plates.

95. There shall be a name plate, showing in raised letters and figures the name of the manufacturer and the year of construction, bolted to the bridge near each end at a point convenient for inspection.

(6) FLOORS.

Types of Floors.

96. The floors may consist of steel floor-beams and stringers, with timber cross-ties supporting the rails, or of one of the solid floor types with ballast.

Floor Members.

97. Floor members shall be designed with special reference to stiffness, and the depth of floor-beams and stringers shall, as a rule, be not less than one-eighth of their length.

98. Specifications for plate girders shall also apply to floor-beams and stringers.

Spacing of Stringers.

99. Stringers usually shall be spaced 6 feet 6 inches center to center. If four stringers are used under one track, each pair shall be spaced symmetrically about the rail.

Stop Angles.

100. Stringers which frame into floor-beams shall have an angle riveted to the top flange at each end to space the end ties at least one inch from the flanges of the floor-beams.

I-Beam Girders.

101. Rolled beams supporting timber decks shall be arranged with not less than two nor more than four beams under each rail. The beams in each group shall be placed symmetrically about the rail, and shall be spaced sufficiently far apart to permit cleaning and painting. They shall be connected by solid web diaphragms near the ends and at intermediate points, spaced not over twelve times the flange width. Bearing plates shall be continuous under each group of beams. End stiffeners shall be used if required by the provisions of paragraph 39.

Floor-Beam Connections.

102. Floor-beams preferably shall be square to the girders or trusses. They shall be riveted directly to the girders or between the posts of through and deck truss spans. End floor-beams shall be used in square end bridges.

End Connection Angles.

103. The legs of stringer connection angles shall be not less than 4 inches in width, and not less than ⅝-inch in thickness. Shelf angles

Floors—Bracing.

shall be provided to support the stringers during erection, but the connection angles shall be sufficient to carry the whole load. Stringers preferably shall be riveted between the floor-beams. Rivets in connection angles shall be spaced closer at the bottom of the angles than at the top.

Stringer Frames.

104. Where two lines of stringers are used under each track in panels more than 30 feet in length, they shall be connected by cross frames.

Solid Floor Connections.

105. Solid floors shall be connected to the girders or trusses by angles not less than ½-inch thick; one angle on each side of the web of I-beams and one on each of the vertical members of troughs.

Proportioning Solid Floors.

106. Solid floors shall be proportioned by the moments of inertia of the sections, using the net areas of the component parts.

(7) BRACING.

Design of Bracing.

107. Lateral, longitudinal and transverse bracing shall be composed of shapes with riveted connections. Lateral bracing shall have concentric connections to chords at end joints, and preferably throughout. The connections between the lateral bracing and the chords shall be designed to avoid, as far as practicable, any bending stress in the truss members.

108. When a double system of bracing is used, both systems may be considered simultaneously effective if the members meet the requirements, both as tension and compression members.

Lateral Bracing.

109. Bottom lateral bracing shall be provided in all bridges except deck plate girder spans less than 70 feet long from which it may be omitted.

110. Top lateral bracing shall be provided in deck spans and in through spans having sufficient head room.

Portal and Sway Bracing.

111. Deck truss spans shall have vertical sway bracing at each panel point. They shall also have bracing in the planes of the end posts, proportioned to transfer the end reaction of the top lateral system to the masonry.

112. Through truss spans shall have portal bracing, with knee braces, as deep as the specified clearance will allow.

113. Through truss spans shall have sway bracing at each intermediate panel point if the height of the trusses is such as to permit of a depth of 6 feet or more for the bracing. When the height of the trusses will not permit of such depth, the top lateral struts shall be of the same depth as the chord and shall have knee braces.

Bracing—Plate Girders.

Cross-Frames.

114. Deck plate girder spans shall be provided with cross-frames at each end proportioned to resist centrifugal and lateral forces, and shall have intermediate cross-frames at intervals not exceeding 18 feet.

Laterals.

115. The smallest angle to be used in lateral bracing shall be 3½ by 3 by ⅜ inches. There shall be not less than three rivets at each end connection of the angles. Angles shall be connected at their intersections by plates.

Clearance.

116. Lateral bracing beneath the track shall be low enough to clear the ties.

Tower Struts.

117. The struts at the base of viaduct towers shall be strong enough to slide the movable shoes when the track is unloaded.

(8) PLATE GIRDERS.

Spacing of Girders.

118. The girders of deck bridges shall be spaced 6 feet 6 inches between centers, except that:

a. In single-track deck spans 75 or more feet in length, the girders shall be spaced in accordance with paragraph 12, but not less than 7 feet 6 inches between centers.

b. In bridges on curves, the girders shall be spaced as shown on the plans.

Design of Plate Girders.

119. Plate girders shall be proportioned either by the moment of inertia of their net section including compression side; or by assuming that the flanges are concentrated at their centers of gravity. In the latter case, one-eighth of the gross section of the web, if properly spliced, may be used as flange section.

Flange Sections.

120. The flange angles shall form as large a part of the gross area of the flange as practicable. Side plates shall not be used except when flange angles exceeding one inch in thickness otherwise would be required.

121. Flange plates shall be equal in thickness to the flange angles or shall diminish in thickness from the flange angles outward. No plate shall have a thickness greater than that of the flange angles.

122. Where flange cover plates are used, one cover plate of the top flange shall extend the full length of each girder. Other flange plates shall extend at least 18 inches beyond the theoretical end.

Plate Girders.

Thickness of Web Plates.

123. The thickness of web plates shall be not less than $\frac{1}{20}\sqrt{D}$, where "D" represents the distance between flanges in inches.

Flange Rivets.

124. The flanges of plate girders shall be connected to the web with a sufficient number of rivets to transfer to the flange section the horizontal shear at any point combined with any load that is applied directly on the flange. One wheel load, where ties rest on the flange, shall be assumed to be distributed over 3 feet.

Flange Splices.

125. Splices in flange members shall not be used except by special permission of the Engineer. Two members shall not be spliced at the same cross-section and, if practicable, splices shall be located at points where there is an excess of section. The net section of the splice shall exceed by 10 per cent. the net section of the member spliced. Flange angle splices shall consist of two angles, one on each side.

Web Splices.

126. Web plates shall be symmetrically spliced by plates on each side. The splice plates for shear shall be the full depth of the girders between flange angles. The splice shall be equal to the web in strength in both shear and moment. There shall be not less than two rows of rivets, staggered, on each side of the joint.

End Stiffeners.

127. Plate girders shall have stiffener angles over end bearings, the outstanding legs of which will extend as nearly as practicable to the outer edge of the flange angles. These end stiffeners shall be proportioned for bearing on the flange angles, and shall be arranged to transmit the end reaction to the pedestals or distribute it over the masonry bearings. They shall be connected to the web by enough rivets to transmit the reaction. End stiffeners shall not be crimped.

Intermediate Stiffeners.

128. The webs of plate girders shall be stiffened by angles at intervals not greater than:

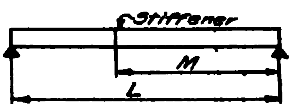


FIG. 4.

(a) Six feet.
(b) The depth of the web.
(c) The distance given by the formula,

$$d = 50t\,[6 - k\,(4k + 1)],$$ in which

d = the distance between rivet lines of stiffeners in inches.
t = the thickness of the web in inches.
k = the ratio $\frac{M}{L}$, shown in Fig. 4, but never less than 0.5.

Plate Girders.

Spans Shipped Riveted.

136. Deck plate girder spans less than 50 feet in length shall be shipped riveted complete, unless otherwise specified.

129. For girders in which the load is applied to the girders at floor-panel points, the stiffener intervals in any panel shall be uniform and based on the value of "*k*" at the end of the panel toward the nearer support.

130. If the depth of the web between the flange angles or side plates is less than 50 times the thickness of the web, intermediate stiffeners may be omitted.

131. Stiffener angles shall be placed at points of concentrated loading. Such angles shall not be crimped.

132. Intermediate stiffeners shall be riveted in pairs to the web of the girder. The outstanding leg of each angle shall not be less than 2 inches plus one-thirtieth of the depth of the girder, nor more than 14 times its thickness.

Gusset Plates in Through Girders.

133. In through plate girder spans, the top flanges shall be braced by means of gusset plates or knee braces with solid webs connected to the floor-beams and extending usually to the clearance line. If the unsupported length of the inclined edge of the gusset plate exceeds 18 inches, the gusset plate shall have one or two stiffening angles riveted along its edge. The gusset plate shall be riveted to a stiffener angle on the girder. Preferably it shall form no part of the floor-beam web.

134. In through plate girder spans with solid floors, there shall be knee-braces with ⅜-inch webs, extending usually to the clearance line, at intervals of about 12 feet. Each knee-brace shall be well riveted to the floor and the girder, especially at the top, and shall have its edge reinforced by one or two angles.

Ends of Through Girders.

135. If through plate girders project two feet or more above the base of the rail, the upper corners shall be rounded to a radius of about one-third of the depth of the girder, but not less than 18 inches, the radius to be a multiple of 6 inches. In multiple span bridges, only the extreme ends shall be rounded. If adjacent spans have different depths and the difference in depth does not exceed 18 inches, the top flanges of the deeper girders shall be curved at the ends to a radius equal to one and one-half times the depth of the girder, so that the depth of the ends will be the same as that of the adjacent girders. If the difference exceeds 18 inches, the corners of the higher girders shall be rounded to a radius not greater than the difference in depth and not greater than one-third of the depth of the deeper girder. Exposed ends of through girders shall be neatly finished with end plates.

Plate Girders—Trusses.

Central Bearings.

137. Plate girders 50 feet or more in length shall be designed with central bearings.

Masonry Bearings.

138. End bearings on masonry shall preferably be raised above the coping by metal pedestals.

139. Sole plates shall be not less than ¾-inch thick and not less in thickness than the flange angles plus ⅛-inch.

Anchor Bolts.

140. Anchor bolts shall be 1¼ inches in diameter and shall extend 12 inches into the masonry. There shall be washers under the nuts. Anchor bolt holes in pedestals and sole plates shall be 1⅝ inches in diameter, except that at expansion points the holes in the sole plates shall be slotted.

(9) TRUSSES.

Type of Truss and Sections of Members.

141. Trusses shall have single intersection web systems and, preferably, inclined end posts. The top chords and end posts shall be made usually of two side segments with one cover plate and with stay plates and lacing on the open side. The bottom chords of riveted trusses shall be symmetrically made, usually of vertical side plates with flange angles. Web members shall be made of symmetrical sections. In pin-connected trusses, the tension chords shall be non-continuous for bending at pin joints.

Camber.

142. The length of members of truss spans shall be such that the camber will be equal to the deflection produced by the combined dead and static live loads.

Riveted Members in Pin-Connected Trusses.

143. Hip verticals (and members performing similar functions) and the two end panels of the bottom chords of pin-connected trusses shall be riveted members.

Eye-Bars.

144. The cross sectional area of the head through the center of the pin hole shall exceed that of the body of the eye-bar by at least 40 per cent. The thickness of the bar shall be not less than one-eighth of the width nor less than one inch, and not greater than 2½ inches. The form of the head shall be submitted to the Engineer for approval before the bars are made. The diameter of the pin shall be not less than seven-eighths of the width of the widest bar attached.

Trusses—Viaducts.

Packing.

145. The eye-bars of a set shall be packed symmetrically about the plane of the truss and as nearly parallel as practicable, but in no case shall the inclination of any bar to the plane of the truss exceed $\frac{1}{16}$-inch per foot. They shall be packed as closely as practicable and arranged so as to produce the least bending moment on the pin. They shall be held against lateral movement, and arranged so that adjacent bars in the same panel will not be in contact.

Gusset Plates.

146. The thickness of gusset plates connecting the various members of the truss shall be proportionate to the stress to be transferred, but shall not be less than ½-inch.

Facilities for Jacking.

147. The end pins of trusses shall project a sufficient distance outside of the faces of the chords to permit making attachments for jacking the span.

Masonry Plates.

148. Masonry plates shall not be less than one inch thick.

(10) VIADUCTS.

Type of Viaduct.

149. Viaducts shall consist usually of alternate tower spans and free spans of plate girders or riveted trusses supported on bents. The tower spans usually shall be not less than 30 feet long.

Bents and Towers.

150. Viaduct bents shall be composed preferably of two supporting columns, and the bents usually shall be united in pairs to form towers. Towers shall be braced, both transversely and longitudinally, with riveted members. In double track towers, riveted diagonal bracing in a horizontal plane shall be used at the top.

Single Bents.

151. Single bents shall have hinged ends, or else have their columns proportioned to resist the bending stresses produced by changes in temperature.

Bottom Struts.

152. The bottom struts of viaduct towers shall be proportioned for the calculated stresses, but in no case for less than one-fourth of the dead load reaction on one pedestal.

Batter.

153. The columns usually shall have a batter transversely of one horizontal to six vertical for single track viaducts, or one horizontal to eight vertical for double track viaducts.

Viaducts—Materials.

Spacing of Girders.

154. In single track viaducts, the girder spacing usually shall be uniform throughout, and shall be determined by the spacing for the longest span in the viaduct, according to the rules specified for deck plate girder spans.

155. In double track viaducts, the girders under each track shall be spaced 6 feet 6 inches between centers, and the inner lines of girders shall be supported by cross-girders framed between and riveted to the posts.

Girder Connections and Bracing.

156. Girders of tower spans shall be riveted at each end to the tops of the posts or cross-girders. Girders between towers shall have one end riveted, and shall be provided with an efficient expansion joint at the other end. No bracing or sway frame shall be common to abutting spans.

157. If neither of the girders under a track rests directly over a tower post, bracing shall be provided to carry the longitudinal force into the tower bracing without producing lateral bending stress in the cross-girders or posts.

Sole and Masonry Plates.

158. Sole and masonry plates shall not be less than ¾-inch thick.

Anchorage for Towers.

159. Anchor bolts for viaduct towers and similar structures shall be designed to engage a mass of masonry the weight of which is at least one and one-half times the uplift.

160. Anchor bolts, washers and other anchorage or grillage materials shall be furnished by the Contractor in time for them to be built into the masonry.

(11) MATERIALS.*

Steel.

161. Steel shall be made by the open hearth process. It shall be of three grades: structural, rivet and cast.

(a) Structural and Rivet Steel.

Properties.

162. Structural and rivet steel shall conform to the following requirements as to chemical and physical properties:

*Specifications for materials conform to A.S.T.M. Standards, Serials A7-16, A27-16 and A48-18, except paragraphs 183 and 184.

Materials, Structural and Rivet Steel.

	Structural Steel	Rivet Steel
Phosphorus, maximum		
Acid	.06 per cent.	.04 per cent.
Basic	.04 per cent.	.04 per cent.
Sulphur, maximum	.05 per cent.	.045 per cent.
Tensile strength, pounds per square inch	55,000 to 65,000	46,000 to 56,000
Yield point, pounds per sq. in., minimum	0.5 Tens. Str.	0.5 Tens. Str.
Elongation in 8 in., minimum, per cent	$\frac{1500000}{\text{Tens. Str.}}$	$\frac{1500000}{\text{Tens. Str.}}$
Elongation in 2 in., minimum, per cent	22	

Ladle Analyses.

163. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus and sulphur. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the Engineer, and shall conform to the requirements specified in paragraph 162.

Check Analyses.

164. Analyses may be made by the purchaser from finished material representing each melt. The phosphorus and sulphur content thus determined shall not exceed that specified herein by more than 25 per cent.

Specimen Tension Tests of Eye-Bar Material.

165. In order to meet the required minimum tensile strength of full size annealed eye-bars, the Engineer may determine the tensile strength to be obtained in specimen tests, the range not to exceed 14,000 lb. per sq. in. The material shall conform to the requirements as to physical properties other than that of tensile strength, specified in paragraph 162.

Yield Point.

166. The yield point shall be determined by the drop of the beam of the testing machine.

Speed of Testing Machine.

167. The cross-head speed of the testing machine shall be such that the beam of the machine can be kept balanced, but in no case shall the values given in the following table be exceeded:

Specified Minimum Tensile Strength of Material, lbs. per sq. in.	Grge Dength, in.	Maximum Cross-head Speed, (ins. per minute) in Determining	
		Yield Point	Tensile Strength
80,000 or under	8	0.50	2.0
	2	2.00	6.0
Over 80,000	2	0.25	1.0
	8	0.50	2.0

Materials, Structural and Rivet Steel.

Modifications in Elongation.

168. For structural steel over ¾-inch in thickness, a deduction of one from the percentage of elongation in 8 inches specified in paragraph 162 shall be made for each increase of ⅛-inch in thickness above ¾-inch, to a minimum of 18 per cent.

169. For structural steel under $\frac{5}{16}$-inch in thickness, a deduction of 2.5 from the percentage of elongation in 8 inches specified in paragraph 162 shall be made for each decrease of $\frac{1}{16}$-inch in thickness below $\frac{5}{16}$-inch.

Bend Tests.

170. The test specimens for plates, shapes, and bars, except as specified in paragraphs 171, 172 and 173, shall bend cold through 180 degrees without cracking on the outside of the bent portion, as follows:

(a) For material ¾-inch or under in thickness, flat on itself.

(b) For material over ¾-inch to and including 1¼ inches in thickness, around a pin the diameter of which is equal to the thickness of the specimen.

(c) For material over 1¼ inches in thickness, around a pin the diameter of which is equal to twice the thickness of the specimen.

171. The test specimens for eye-bar flats shall bend cold through 180 degrees without cracking on the outside of the bent portion as follows:

(a) For material ¾-inch or under in thickness, around a pin the diameter of which is equal to the thickness of the specimen.

(b) For material over ¾-inch to and including 1¼ inches in thickness, around a pin the diameter of which is equal to twice the thickness of the specimen.

(c) For material over 1¼ inches in thickness, around a pin the diameter of which is equal to three times the thickness of the specimen.

172. The test specimens for pins, rollers and other bars, when prepared as specified in paragraph 178, shall bend cold through 180 degrees around a one inch pin without cracking on the outside of the bent portion.

173. The test specimens for rivet steel shall bend cold through 180 degrees flat on themselves without cracking on the outside of the bent portion.

Test Specimens.

174. Tension and bend test specimens shall be taken from rolled steel in the condition in which it comes from the rolls, except as specified in paragraph 175.

175. Tension and bend test specimens for pins and rollers shall be taken from the finished bars after annealing when annealing is specified.

Materials, Structural and Rivet Steel.

176. Tension and bend test specimens for plates, shapes and bars (except as specified in paragraphs 177, 178 and 179) shall be of the full thickness of material as rolled. They may be machined to the form and dimensions shown in Fig. 5, or with both edges parallel, except that bend test specimens for eye-bar flats may have three rolled sides.

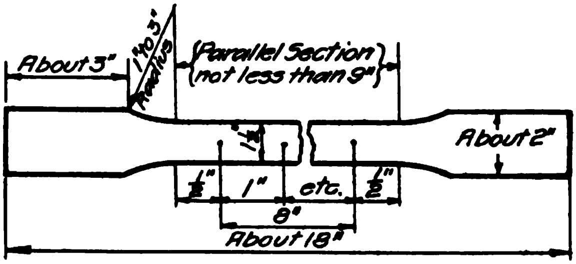


FIG. 5.

177. Tension and bend test specimens for plates and tension test specimens for eye-bar flats over 1½ inches in thickness may be machined to a thickness or diameter of at least ¾-inch for a length of at least 9 inches.

178. Tension test specimens for pins, rollers, and bars (except eye-bar flats) over 1½ inches in thickness or diameter may conform to the dimensions shown in Fig. 6. In this case, the ends shall be of a form to fit the holders of the testing machine in such a way that the load will be axial. Bend test specimens may be 1 by ½-inch in section. The axis of the specimen shall be located at any point midway between the center and surface and shall be parallel with the axis of the bar.

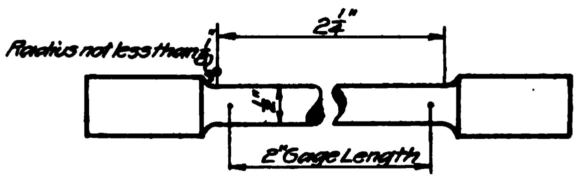


FIG. 6.

NOTE.—The gage length, parallel portions and fillets shall be as shown, but the ends may be of any form which will fit the holders of the testing machine.

179. Tension and bend test specimens for rivet steel shall be of the full-size section of the bars as rolled.

Number of Tests.

180. One tension and one bend test shall be made from each melt, except that if material from one melt differs ⅜-inch or more in thickness,

Materials, Structural and Rivet Steel.

one tension and one bend test shall be made from both the thickest and the thinnest material rolled.

181. If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

182. If the percentage of elongation of any tension test specimen is less than that specified in paragraph 162, and any part of the fracture is more than ¾-inch from the center of the gage length of a 2 inch specimen or is outside the middle third of the gage length of an 8 inch specimen, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

Character of Fracture.

183. Test specimens of structural or rivet steel shall show a fracture of uniform, silky appearance, of bluish gray or dove color, and entirely free from granular, black and brilliant specks.

Surface Defects.

184. Finished rolled material shall be free from cracks, flaws, injurious seams, blisters, ragged and imperfect edges, and other surface defects. It shall have a smooth finish, and shall be straightened in the mill before shipment.

Permissible Variations in Weight and Thickness.

185. The cross-section or weight of each piece of steel shall not vary more than 2.5 per cent. from that specified, except in the case of sheared plates, which shall be covered by the following permissible variations. One cubic inch of rolled steel is assumed to weigh 0.2833 lb.

(a) When ordered to weight per square foot, the weight of each lot in each shipment shall not vary from the weight ordered more than the amount given in Table I. The term "lot" as applied to Table I means all of the plates of each group width and group weight (page 678).

(b) When ordered to thickness, the thickness of each plate shall not vary more than 0.01 inch under that ordered. The overweight of each lot in each shipment shall not exceed the amount given in Table II. The term "lot" as applied to Table II means all of the plates of each group width and group thickness (page 678).

Marking.

186. The name or brand of the manufacturer and the melt number shall be legibly stamped or rolled on all finished material, except that rivet and lattice bars and other small sections shall, when loaded for shipment, be separated properly and marked for identification. The identification marks shall be stamped legibly on the end of each pin and roller. The melt number shall be marked legibly by stamping if practicable, on each test specimen.

Materials, Structural and Rivet Steel.

Table I.—Permissible Variations of Plates Ordered to Weight.

ORDERED WEIGHT, Lbs. Per Sq. Ft.	PERMISSIBLE VARIATIONS IN AVERAGE WEIGHTS PER SQUARE FOOT OF PLATES FOR WIDTHS GIVEN, EXPRESSED IN PERCENTAGES OF ORDERED WEIGHTS																	
	Under 48 In.		48 to 60 In., Excl.		60 to 72 In., Excl.		72 to 84 In., Excl.		84 to 96 In., Excl.		96 to 108 In., Excl.		108 to 120 In., Excl.		120 to 132 In., Excl.		132 in. or Over.	
	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.
Under 5	5	3	5.5	3	6	3	7	3	....	....	....	....	....	....	....	....	....	....
5 to 7.5, excl	4.5	3	5	3	5.5	3	6	3	....	....	....	....	....	....	....	....	....	....
7.5 to 10 excl	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	....	....	....	....
10 to 12.5, excl	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	9	3
12.5 to 15, excl	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3
15 to 17.5, excl	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3
17.5 to 20, excl	2.5	2	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3
20 to 25, excl	2	2	2.5	2	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3
25 to 30, excl	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	4.5	3	5	3
30 to 40, excl	2	2	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	4.5	3
40 or over	2	2	2	2	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3

NOTE—The weight per square foot of individual plates shall not vary from the ordered weight by more than 1¼ times the amount given in this table.

Table II.—Permissible Overweights of Plates Ordered to Thickness.

ORDERED THICKNESS, INCHES.	PERMISSIBLE EXCESS IN AVERAGE WEIGHTS PER SQUARE FOOT OF PLATES FOR WIDTHS GIVEN, EXPRESSED IN PERCENTAGES OF NOMINAL WEIGHTS.								
	Under 48 In.	48 to 60 In., Excl.	60 to 72 In., Excl.	72 to 84 In., Excl.	84 to 96 In., Excl.	96 to 108 In., Excl.	108 to 120 In., Excl.	120 to 132 In., Excl.	132 In. or Over.
Under 1/8	9	10	12	14	....	....	....	....	....
1/8 to 3/16, excl	8	9	10	12	....	....	....	....	....
3/16 to 1/4, excl	7	8	9	10	12	....	....	....	....
1/4 to 5/16, excl	6	7	8	9	10	12	14	16	19
5/16 to 3/8, excl	5	6	7	8	9	10	12	14	17
3/8 to 7/16, excl	4.5	5	6	7	8	9	10	12	15
7/16 to 1/2, excl	4	4.5	5	6	7	8	9	10	13
1/2 to 5/8, excl	3.5	4	4.5	5	6	7	8	9	11
5/8 to 3/4, excl	3	3.5	4	4.5	5	6	7	8	9
3/4 to 1	2.5	3	3.5	4	4.5	5	6	7	8
1 or over	2.5	2.5	3	3.5	4	4.5	5	6	7

Materials, Cast Steel.

(b) Cast Steel.

Process.

187. The steel shall be made by the open hearth or the crucible process.

Heat Treatment.

188. Castings shall be annealed.

Chemical and Physical Properties.

189. The chemical and physical properties shall conform to the following limits:

Elements Considered		*Min. Ten. Strength lbs. per sq. in.*	*Min. Yield Point lbs. per sq. in.*	*Min. Elongation in 2 in.*	*Min. Reduction of Area*
Phosphorus not over	0.05%	60,000	0.45 Tens. Str.	22%	30%
Sulphur not over	0.05%				

Ladle Analyses.

190. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus and sulphur. This analysis shall be made from drillings taken at least ¼-inch beneath the surface of a test ingot obtained during the pouring of the melt. The chemical composition thus determined shall be reported to the Engineer.

Check Analyses.

191. Check analyses may be made by the Engineer from a broken tension or bend test specimen. The phosphorus and sulphur content thus determined shall not exceed that specified in paragraph 189 by more than 20 per cent. Drillings for analysis shall be taken not less than ¼-inch beneath the surface.

Yield Point.

192. The yield point shall be determined by the drop of the beam of the testing machine. The speed of the machine shall conform to the requirements of paragraph 167.

Bend Test.

193. The test specimen shall bend cold through 120 degrees around a one inch pin without cracking on the outside of the bent portion.

Test Specimens.

194. Sufficient test bars from which the test specimens required by paragraph 197 may be selected, shall be attached to castings weighing 500 lbs. or over, when the design of the castings will permit. If the castings weigh less than 500 lbs., or are of such a design that test bars cannot be attached, two test bars shall be cast to represent each melt. Test bars shall be annealed with the castings they represent.

195. Tension test specimens shall conform to the dimensions shown in Fig. 6 (page 676).

Materials, Cast Steel—Cast Iron.

196. Bend test specimens shall be machined to 1 inch by ½-inch in section with corners rounded to a radius not over $\frac{1}{16}$-inch.

Number of Tests.

197. One tension and one bend test shall be made from each annealing charge. If more than one melt is represented in the annealing charge, one tension and one bend test shall be made from each melt.

198. If the percentage of elongation of any tension test specimen is less than that specified in paragraph 189 and any part of the fracture is more than ¾-inch from the center of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

199. If the results of the physical tests of any test lot do not conform to the requirements specified, the manufacturer may re-anneal such lot not more than twice and retests shall be made as specified in paragraph 189.

Workmanship and Finish at Foundry.

200. The castings shall conform substantially to the sizes and shapes of the patterns and shall be made in a workmanlike manner. The castings shall be free from injurious defects. Minor defects, which do not impair the strength of the castings, may, with the approval of the Engineer, be welded by an approved process. The defects first shall be cleaned out to solid metal and, after welding, the castingss shall be annealed, if required by the Engineer.

Inspection at Foundry.

201. Tests and inspection shall be made at the place of manufacture prior to shipment, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection.

202. Castings which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

(c) Cast Iron.

Process.

203. Cast iron shall be of tough gray iron, and shall be made by the cupola process.

Finish.

204. Castings shall be true to pattern and free from excessive shrinkage. They shall be free from cracks, cold shuts, blow holes and other flaws.

Chemical Composition.

205. The sulphur content of cast iron shall not exceed the following:

Light castings	0.10 per cent.
Medium castings	0.10 per cent.
Heavy castings	0.12 per cent.

Materials, Cast Iron—Workmanship.

Drillings taken from the fractured ends of the transverse test bars shall be used for the sulphur determinations. One determination shall be made from each set of bars.

Classification.

206. Castings shall be classified as light, medium and heavy.
   (a) Light castings are those having any section less than ½-inch thick.
   (b) Heavy castings are those having no section less than two inches thick.
   (c) Medium castings are those not included in either of the two classes above.

Test Bar.

207. Tests shall be made on the "Arbitration Test Bar" of the American Society for Testing Materials, as shown by Fig. 1, Serial A48-18.

Tension Tests.

208. Tension tests will be made only when specified by the Engineer and at the expense of the Company.

Number of Tests.

209. Two sets of two test bars each shall be cast from each melt in thoroughly dried green sand moulds, one set from the first iron poured and the other set from the last iron poured. Where the melt exceeds 20 tons, an additional set of two bars shall be cast from each additional 20 tons or fraction thereof.

Transverse Tests.

210. A transverse test of each bar cast shall be made. The load shall be applied at the middle, and the supports shall be spaced 12 inches apart. The load on the test bar at rupture shall be not less than the following:

Light castings	2500 pounds
Medium castings	2900 pounds
Heavy castings	3300 pounds

The deflection at rupture shall in no case be less than 0.10-inch. The rate of application of the load shall be such that a central deflection of 0.10 is produced in from 20 to 40 seconds.

(12) WORKMANSHIP.

Punched Work.*

211. In punched work, holes in material whose thickness is not greater than the diameter of the rivets plus ⅛-inch, generally may be punched full size. Holes in material of greater thickness shall be drilled.

*The work shall be "Punched Work" or "Sub-punched and Reamed Work" as stipulated.

Workmanship.

Sub-Punched and Reamed Work.*

212. In sub-punched and reamed work, holes in material ¾-inch thick and less, used for lateral, longitudinal and sway bracing, lacing, stay plates and diaphragms, may be punched full size.

213. Holes in other material ¾-inch thick and less, shall be sub-punched and reamed.

214. Holes in material over ¾-inch thick shall be drilled.

General.

215. The workmanship and finish shall be equal to the best practice in modern bridge shops. Material at the shops shall be kept clean and protected from the weather as far as practicable.

Straightening Material.

216. Rolled material, before being laid off or worked, must be straight. If straightening or flattening is necessary, it shall be done by methods that will not injure the material. Sharp kinks and bends shall be cause for rejection.

Finish.

217. Shearing and chipping shall be neatly and accurately done and all portions of the work exposed to view shall be neatly finished.

Punched Holes.

218. Full size punched holes shall be 1/16-inch larger than the nominal diameter of the rivets. The diameter of the die shall not exceed the diameter of the punch by more than 3/32-inch. The punching shall be done so accurately that, after assembling, a cylindrical pin ⅛-inch smaller in diameter than the nominal diameter of the punched hole, may be entered in at least 75 of any group of 100 contiguous holes in the same plane. If any holes must be enlarged to admit the rivets, they shall be reamed. Holes must be clean cut, without torn or ragged edges. Poor matching of holes shall be cause for rejection.

Sub-Punched and Reamed Holes.

219. In sub-punched and reamed work, the holes shall be punched 3/16-inch smaller and, after assembling, reamed 1/16-inch larger than the nominal diameter of the rivet. The diameter of the punch used shall be 3/16-inch smaller than the nominal diameter of the rivet and the diameter of the die not more than 3/32-inch larger than the diameter of the punch. Outside burrs shall be removed with a tool making a 1/16-inch fillet.

Accuracy of Punching in Reamed Work.

220. In sub-punched and reamed work, the punching shall be so accurately done that, after assembling and before reaming, a cylindrical

*The work shall be "Punched Work" or "Sub-punched and Reamed Work" as stipulated.

pin 1/8-inch smaller in diameter than the nominal size of the punched hole may be entered, perpendicular to the face of the member, without drifting, in at least 75 of any group of 100 contiguous holes in the same plane. If this requirement is not fulfilled, the badly punched pieces shall be rejected. If any hole will not pass a pin 3/16-inch smaller in diameter than the nominal size of the punched hole, this shall be cause for rejection.

Reaming After Assembling.

221. Reaming shall be done after the pieces forming a built member are assembled and so firmly bolted together that the surfaces are in close contact. Before riveting, they shall be taken apart and any shavings removed, if necessary. When it is necessary to take the members apart for shipping or handling, the respective pieces reamed together shall be so marked that they may be reassembled in the same position in the final setting up. No interchange of reamed parts will be permitted.

Accuracy of Reaming.

222. In reamed work, 85 of any group of 100 contiguous holes in the same plane shall, after reaming, show no offset greater than 1/32-inch between adjacent thicknesses of metal. If any hole shows an offset greater than 1/16-inch, this shall be cause for rejection.

Size of Reamed Holes.

223. Reamed holes shall be cylindrical, perpendicular to the member, and not more than 3/32-inch larger than the nominal diameter of the rivets.

Method of Reaming.

224. Reaming shall be done with twist drills or short taper reamers. Reamers preferably shall not be directed by hand.

Drilling.

225. Drilled holes shall be 1/16-inch larger than the nominal size of the rivet. Burrs on the outside surfaces shall be removed and holes filleted 1/16-inch under rivet heads.

Assembling for Drilling.

226. Connecting parts requiring drilled holes shall be assembled and securely bolted together before drilling.

Accuracy of Drilling.

227. When holes are drilled, 85 of any group of 100 contiguous holes in the same plane shall, after drilling, show no offset greater than 1/32-inch between adjacent thicknesses of metal. If any hole shows an offset greater than 1/16-inch, this shall be cause for rejection.

Shop Assembling.

228. The parts of riveted members shall be well pinned and firmly drawn together with bolts before riveting is commenced. Surfaces in contact shall be painted. Fitting up bolts shall be used in at least one-

Workmanship.

third of the holes unless otherwise directed by the Inspector. Bolts in field connection holes shall be left in place.

229. Solid floor sections shall be assembled to the girders or trusses, or to suitable frames in the shop, and the end connections made to fit.

230. Riveted trusses and skew portals shall be assembled in the shop, the parts adjusted to line and fit, and the holes for field connections drilled or reamed while so assembled. Holes for other field connections, except those in lateral, longitudinal and sway bracing, shall be drilled or reamed in the shop with the connecting parts assembled, or else drilled or reamed to a metal template.

Match-Marking.

231. Connecting parts assembled in the shop for the purpose of reaming or drilling holes in field connections shall be match-marked, and a diagram showing such marks shall be furnished the Engineer.

Rivets.

232. The size of rivets called for on the plans shall be the size of the rivet before heating.

233. Rivets shall be carefully selected, and shall be free from fins on the under side of the head.

234. Rivet heads, when not countersunk or flattened, shall be of approved shape and of uniform size for the same diameter of rivet. Rivet heads shall be full, neatly made, concentric with the rivet holes, and in full contact with the surface of the member.

Riveting.

235. Rivets shall be heated uniformly to a light cherry red and driven while hot. Rivets, when heated and ready for driving, shall be free from slag, scale and carbon deposit. When driven, they shall completely fill the holes. Loose, burned or otherwise defective rivets shall be replaced. In removing rivets, care shall be taken not to injure the adjacent metal, and, if necessary, they shall be drilled out. Caulking or re-cupping will not be permitted.

236. Rivets shall be driven by direct-acting riveters where practicable. The riveters shall retain the pressure after the upsetting is completed.

237. When necessary to drive rivets with a pneumatic riveting hammer, a pneumatic bucker shall be used for holding up, when practicable.

Field Rivets.

238. Field rivets shall be furnished in excess of the nominal number required to the amount of 15 per cent. plus ten rivets, for each size and length.

Turned Bolts.

239. Wherever bolts are used in place of rivets to transmit shear, the holes shall be reamed parallel and the bolts shall make a tight fit

Workmanship.

with the threads entirely outside of the holes. A washer not less than ¼-inch thick shall be used under each nut. Bolts shall not be used in place of rivets except by special permission of the Engineer.

Planing Sheared Edges.

240. Sheared edges of material more than ¾-inch in thickness and carrying calculated stress shall be planed to a depth of $\frac{1}{16}$-inch. Re-entrant cuts shall be filleted by drilling before cutting.

Drifting.

241. The drifting done during assembling shall be only such as to bring the parts into position, and not sufficient to enlarge the holes or distort the metal.

Lacing Bars.

242. The ends of lacing bars shall be neatly rounded, unless otherwise called for.

Fit of Stiffeners.

243. Stiffeners under the top flanges of deck girders and at all bearing points shall be milled to bear against the flange angles. Other stiffeners must fit sufficiently tight against the flange angles to exclude water after being painted. Fillers and splice plates shall fit within ⅛-inch at each end.

Web Plates.

244. Web plates of girders which have no cover plates shall be flush with the backs of the flange angles or project above them not more than ⅛-inch, unless otherwise called for. When web plates are spliced, not more than ¼-inch clearance between ends of plates will be allowed.

245. Web plates of girders which have cover plates may be ½-inch less in width than the distance back to back of flange angles.

Facing Floor Beams, Stringers and Girders.

246. The main sections of floor beams, stringers and girders having end connection angles shall be faced to length after riveting and the connection angles accurately set flush with the entire face and true to the faced ends. If facing is done after the connection angles are riveted in place, the thickness of the angles shall not be reduced more than $\frac{1}{16}$-inch, at any point.

Finished Members.

247. Finished members shall be true to line and free from twists, bends and open joints.

Abutting Joints.

248. Abutting joints in tension and compression members, and in girder flanges, shall be faced and brought to an even bearing.

Workmanship.

Eye-Bars.

249. Eye-bars shall be straight, true to size, and free from twists, folds in the neck or head, and other defects. The heads shall be made by upsetting, rolling or forging. Welding will not be allowed. The form of the heads will be determined by the dies in use at the works where the eye-bars are made, if satisfactory to the Engineer, but the manufacturer shall guarantee the bars to break in the body when tested to rupture. The thickness of the head and neck shall not over-run more than 1/16-inch for bars 8 inches or less in width, 1/8-inch for bars over 8 inches and not more than 12 inches in width, and 3/16-inch for bars over 12 inches in width.

250. Eye-bars which are to be placed side by side in the structure shall be bored so accurately that, upon being placed together, the pins will pass through the holes at both ends at the same time without driving. Eye-bars shall have both ends bored at the same time.

Annealing.

251. All eye-bars shall be annealed by heating uniformly to the proper temperature followed by slow and uniform cooling in the furnace. Proper instruments shall be provided for determining at all times the temperature of the bars.

252. Other steel which has been partially heated shall be properly annealed except where used in minor parts.

Boring Pin Holes.

253. Pin holes shall be bored true to gage, smooth, straight, at right angles with the axis of the member and parallel with each other, unless otherwise required. The variation from the specified distance from outside to outside of pin holes in tension members, or from inside to inside of pin holes in compression members, shall not exceed 1/32-inch. In built-up members the boring shall be done after the member is riveted.

Boring Pins.

254. Pins above 8 inches in diameter shall have a hole bored longitudinally through the center of each not less than 2 inches in diameter.

Pin Clearances.

255. The difference in diameter between the pin and the pin hole shall be 1/50-inch for pins up to 5 inches in diameter, and 1/32-inch for larger pins.

Pins and Rollers.

256. Pins and rollers shall be accurately turned to gage and shall be straight, smooth and free from flaws.

Screw Threads.

257. Screw threads shall make close fits in the nuts and shall be U. S. Standard, except that for diameters greater than 1⅜ inches, they shall be made with six threads to an inch.

Workmanship—Weighing and Shipping.

Welds.

258. Welds in steel will not be allowed, except to remedy minor defects.

Forging Pins.

259. Pins above 7 inches in diameter shall be forged under a steam hammer and annealed.

Bearing Surfaces Planed.

260. The top and the bottom surfaces of base and cap plates of columns and pedestals, except those in contact with masonry, shall be planed, and parts of members in contact with them shall be faced to fit. Connection angles for base plates and cap plates shall be riveted to compression members before the members are faced.

261. Sole plates of plate girders shall have full contact with the girder flanges, and shall be planed on their lower surfaces. Masonry plates shall be planed on the top surfaces. Cast pedestals shall be planed on the top surfaces and shall have the bottom surfaces rough finished.

Pilot Nuts.

262. Two pilot nuts and two driving nuts shall be furnished for each size of pin, unless otherwise specified.

(13) WEIGHING AND SHIPPING.

Weight Paid for.

263. The payment for pound price contracts shall be based on the scale weight of the metal in the fabricated structure, including field rivets shipped. The weight of the field paint, cement and fitting-up bolts, if furnished, boxes and barrels used for packing, and material used for staying or supporting members on cars, shall be excluded.

Variation in Weight.

264. If the weight of any member is more than 2½ per cent. under the computed weight, it shall be cause for rejection.

265. The greatest allowable variation of the total scale weight of any structure from the weights computed from the approved shop drawings shall be 1½ per cent. Any weight in excess of 1½ per cent. above the computed weight shall not be paid for by the Company.

Computed Weight.

266. The weights of rolled shapes, and of plates, up to and including 36 inches in width, shall be computed on the basis of their nominal weights and dimensions, as shown on the approved shop drawings, deducting for copes, cuts and open holes.

267. The weights of plates wider than 36 inches shall be computed on the basis of their dimensions, as shown on the approved shop draw-

ings, deducting for cuts and open holes. To this shall be added one-half of the allowed percentages of overrun in weight given in paragraph 185.

268. The weight of heads of shop driven rivets shall be included in the computed weight.

269. The weights of castings shall be computed from the dimensions shown on the approved shop drawings, with an addition of 10 per cent. for fillets and overrun.

Weighing of Members.

270. Finished work shall be weighed in the presence of the Inspector, if practicable. The Contractor shall furnish satisfactory scales and do the handling of the material for weighing.

Marking and Shipping.

271. Members weighing more than 5 tons shall have the weight marked thereon. Bolts and rivets of one length and diameter, and loose nuts or washers of each size, shall be packed separately. Pins, other small parts, and small packages of bolts, rivets, washers and nuts shall be shipped in boxes, crates, kegs or barrels, but the gross weight of any package shall not exceed 200 pounds. A list and description of the contained material shall be plainly marked on the outside of each package, box or crate.

272. Long girders shall be loaded and marked so that they will arrive at the bridge site in position for erection without turning.

(14) PAINTING.

Shop Cleaning and Painting.

273. Unless otherwise specified, steel work, before leaving the shop, shall be thoroughly cleaned and given one coat of approved paint, well worked into joints and open spaces. The paint shall not be applied until the work has been accepted by the Inspector. Cleaning shall be done with steel brushes, hammers, scrapers and chisels. Oil and grease shall be removed by wiping with benzine or gasoline.

Surfaces in Contact.

274. Surfaces coming in contact shall be cleaned and given one coat of paint on each surface before assembling.

Erection Marks.

275. Erection marks shall be painted on painted surfaces.

Painting in Damp or Freezing Weather.

276. Painting shall not be done in damp or freezing weather except under cover, and the steel must be free from moisture or frost when the paint is applied. Material painted under cover in damp or freezing weather shall be kept under cover until the paint is dry.

Painting—Inspection—Full-Size Tests.

Mixing of Paint.

277. Paint shall be thoroughly mixed before applying, and the pigments shall be kept in suspension by means of mechanical mixers.

Machine Finished Surfaces.

278. Machine finished surfaces of steel shall be coated with white lead and tallow, applied hot as soon as the surfaces are finished and accepted by the Inspector.

(15) INSPECTION.

Facilities for Inspection.

279. Facilities for inspection of material and workmanship in the mill, shop and field, shall be furnished by the Contractor and Erector to the Inspectors, and the Inspectors shall be allowed free access to the necessary parts of the premises.

Mill Orders and Shipping Statements.

280. The Contractor shall furnish the Engineer with as many copies of material orders and shipping statements as the Engineer may direct. The weights of the individual members shall be shown.

Notice of Rolling.

281. The Contractor shall give ample notice to the Engineer of the beginning of rolling at the mill, and of work at the shop, so that inspection may be provided. No material shall be rolled nor work done before the Engineer has been notified where the orders have been placed.

Cost of Testing.

282. The Contractor shall furnish, without charge, test specimens, as specified herein, and all labor, testing machines and tools necessary to make the specimen and full size tests.

Inspector's Authority.

283. The Inspector shall have the power to reject materials or workmanship which do not come up to the requirements of these specifications; but in cases of dispute, the Contractor or Erector may appeal to the Engineer, whose decision shall be final.

Rejections.

284. The acceptance of any material or finished members by the Inspector shall not be a bar to their subsequent rejection, if found defective.

285. Rejected material or workmanship shall promptly be replaced or made good by the Contractor or Erector.

(16) FULL-SIZE TESTS.

Full-Size Tests of Eye-Bars.

286. One eye-bar from each annealing charge shall be tested full-size, if the Engineer so desires, but the number and size of the bars to

Full-Size Tests—Erection.

be tested shall be stipulated by the Engineer before the mill order is placed.

287. The test bars shall be of the same size as the bars to be used in the structure and of the same length, within the capacity of the testing machine. They shall be selected by the Inspector, preferably after annealing. Test bars representing bars too long for the testing machine shall be selected from the full length bar material after the heads on one end have been formed. They shall be cut to the greatest length which can be tested. They shall have the second head formed upon them and shall be annealed together with the bars which they represent.

288. Full-size tests of eye-bars shall show a yield point of not less than 29,000 pounds per square inch, an ultimate strength of not less than 54,000 pounds per square inch, and an elongation of not less than 10 per cent. in a length of 20 feet measured in the body of the bar. The fracture shall show a silky or finely granular structure throughout.

289. If a bar fails to meet the requirements of paragraph 288, two additional bars from the same annealing charge shall be tested. If the failure of the first test bar is on account of the character of the fracture only, the charge may be reannealed before the additional bars are tested.

290. If two of the three bars tested fail, the bars from the annealing charge represented shall be rejected.

291. A failure in the head of a bar shall not be cause for rejection if the other requirements are fulfilled.

292. A record of the annealing charges shall be furnished the Engineer showing the bars included in each charge and the treatment they receive.

293. Bars thus tested which meet the requirements of the specifications shall be paid for by the Company at the same unit prices as the structure, less their scrap value. Bars which fail to meet the requirements of the specifications, and all bars from rejected annealing charges, shall be at the Contractor's expense.

(17) ERECTION.

Contracts Involving Fabrication and Erection.

294. In contracts involving erection by the Contractor, wherever the word Erector is used in these Specifications, it shall be understood to refer to the Contractor.

Notice of Beginning Erection.

295. The Erector shall give the Engineer formal notice of his desire to begin operations, and no work shall be done until authority has been received in reply to such notice.

Special Specifications for Erection.

296. Special supplementary specifications shall be prepared for each contract involving erection. These specifications shall define the obliga-

Erection.

tion of the Company and the work to be done, and shall state the conditions under which the work shall be done, such as traffic, unloading and storing material, sidetrack facilities, work train, switching and flagging service and transportation of men and equipment.

Storing Material.

297. Material which is unloaded and stored pending erection, shall be laid on skids above the ground, so as to be kept clean and properly drained. Material shall be so stored and handled as to avoid injury to it. Any piece damaged in handling by the Erector may be rejected, and, if rejected, shall be replaced at his expense.

Work of Erector.

298. Unless otherwise agreed upon, the Erector shall furnish, erect and maintain the falsework, take down the old bridge (if such exists), erect the metal work of the new bridge complete, and, on completion of the work, remove the falsework and other obstructions. Holes in the masonry for anchor bolts shall be drilled by the Erector, who shall set the bolts in Portland cement grout.

Falsework.

299. Before the erection is begun, the Erector shall submit to the Engineer, for approval, plans for falsework and a complete description of erection equipment and methods.

Lines, Levels and Marks.

300. The Erector shall erect the superstructure in accordance with the lines and levels shown on the plans and indicated on the ground by the Engineer. The erection marks and match-marks shall be followed. He shall guard with care the marks and stakes set by the Engineer for the Erector's use, or for the use of the Company or other contractors. If such stakes or marks are injured, lost or removed, due to the Erector's negligence, he shall bear the expense of having them reset.

Removing and Loading Old Structures.

301. In the removal of old structures the Erector shall follow the directions of the Engineer in regard to the manner of dismantling, piling and loading, and shall use care to preserve all parts intact for re-erection, marking them in accordance with a diagram to be furnished him.

Removal of Tracks.

302. The Company will remove and replace its tracks on the structure when necessary.

Changes in Grade and Line.

303. If the track on the new structure is to be placed at an elevation or location different from that on the old, the Erector shall furnish

Erection.

the temporary material and do the work necessary to make the change in a manner satisfactory to the Engineer. The Erector shall give due notice to the Engineer of the time when he proposes to make such changes so that the Company may make the changes in the approaches. The methods to be used and the time to be selected for such changes shall be subject to the approval of the Engineer.

Masonry Changes.

304. If the old masonry is to be rebuilt or modified to suit the new superstructure, the Erector shall arrange his falsework and method of erection to facilitate such reconstruction.

Field Riveting.

305. Field riveting shall be done to the satisfaction of the Engineer.

306. Rivets in splices of compression chords and trestle posts shall not be driven until the abutting surfaces have been brought into contact throughout, and submitted to the full dead load stress.

307. Field riveting preferably shall be done by pneumatic riveters of approved make. A pneumatic bucker shall be used for holding up when pneumatic riveters are used for driving. Rivets over ⅞-inch in diameter shall not be driven by hand.

Field Painting by the Erector.

308. After erection, the heads of field rivets and parts where the paint has been rubbed off in transportation or during erection shall be given one coat of the shop paint by the Erector. The painting of the field rivet heads shall be done promptly after their acceptance.

309. Parts not accessible for painting after erection and not in riveted contact, and the tops of stringers and girders which are to carry ties, shall be given two coats of field paint by the Erector before erecting.

Other Field Painting.

310. After erection, the structure shall be cleaned and given two coats of approved paint by the Erector.

Second Coat.

311. At least 48 hours must elapse between the applications of any two coats of paint.

Bolts.

312. Bolts shall not be used instead of rivets except by special permission of the Engineer.

Field Bolting.

313. Splices and field connections shall have 50 per cent. of the holes filled with bolts and drift pins (of which one-fifth shall be drift pins) before riveting. Splices and connections carrying traffic during erection shall have 75 per cent. of the holes so filled.

Erection.

Operation of the Railroad.

314. The Erector shall not, without the special permission of the Engineer, interfere with the operation of the railroad or the work of other contractors, or close any thoroughfare by land or water.

Accidents and Damages.

315. The Erector shall take precautions to guard against accidents and damage to persons and property, and any expense in consequence of such accidents or damage shall be assumed by him.

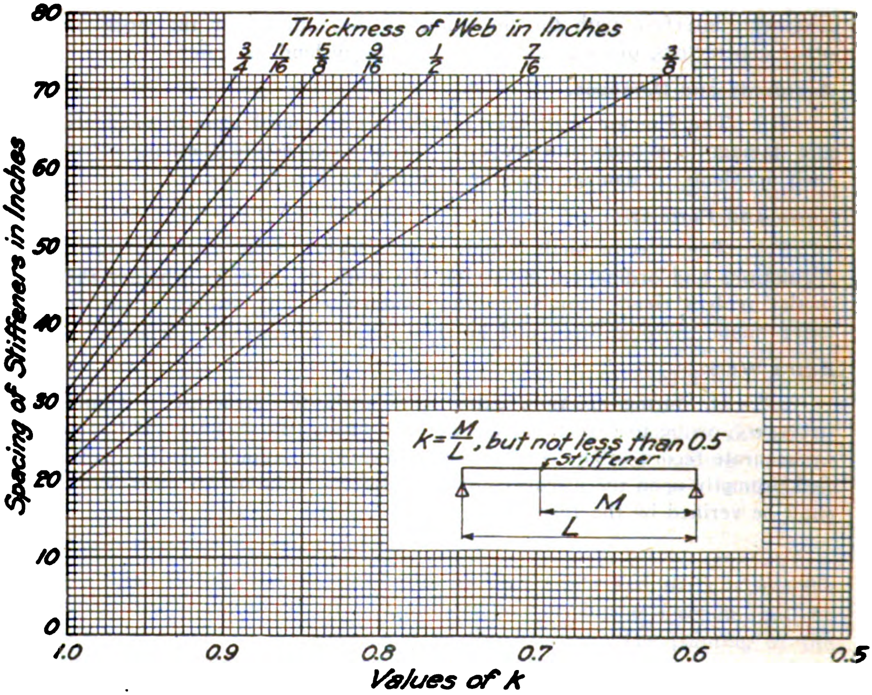
Laws and Permits.

316. The Erector shall comply with Federal, State and local laws, regulations and ordinances governing the work of erection, whether the work involves rivers, canals or other waterways, city streets, roads or other public thoroughfares, and he shall obtain all necessary permits.

Extra Work.

317. If, during erection, extra work upon the structure is found necessary, owing to defective shop work or fitting, the Erector shall keep an accurate record of the cost of such work. The Engineer shall be notified promptly upon the discovery of such defects. Claims for extra work shall be verified by the Inspector.

Plate I.



Formula for Spacing Stiffeners of Plate Girders.

$$d = 50t\,[6 - k\,(4k + 1)],\ \text{in which}$$

d = the distance between rivet lines of stiffeners in inches.
t = the thickness of web in inches.
k = the ratio $\frac{M}{L}$, but never less than 0.5.

This formula is derived from the formula,

$$d = \frac{t}{40}\,(12{,}000 - s),$$

as given in "Modern Framed Structures," by Johnson, Bryan and Turneaure, Part III, page 174, and is based on shears derived from the specification loading, and the assumption that the shear in the gross area of the web at the end equals 10,000 pounds per square inch.

REPORT OF COMMITTEE VIII—ON MASONRY.

F. L. Thompson, *Chairman;*
R. Armour,
G. E. Boyd,
H. A. Cassil,
C. S. Coe,
T. L. Condron,
J. K. Conner,
C. S. Davis,
J. L. Harrington,
W. K. Hatt,
L. J. Hotchkiss,
Richard L. Humphrey,
J. J. Yates, *Vice-Chairman;*
Noah Johnson,
M. S. Ketchum,
W. M. Kinney,
W. S. Lacher,
A. E. Owen,
W. M. Ray,
C. P. Richardson,
G. H. Scribner, Jr.,
F. P. Sisson,
J. E. Smith,
Job Tuthill,

Committee.

To the American Railway Engineering Association:

Your Committee on Masonry presents herewith its annual report for the year 1918.

The following Sub-Committees were appointed to deal with the subjects assigned by the Board of Direction:

Sub-Committee (1). Make critical examination of the subject-matter in the Manual and submit definite recommendations for changes.

A. E. Owen, Chairman; H. A. Cassil, C. S. Davis, M. S. Ketchum.

The Committee has no recommendations to make at this time. The question of revising the definitions in the Manual has received consideration and it has been decided to completely revise this portion of the Manual next year.

Sub-Committee (2). Report on designs and recommended specifications for construction of concrete culvert pipe.

Job Tuthill, Chairman; W. M. Kinney, G. H. Scribner, Jr., B. A. Underwood.

Report on this subject appears in Appendix A.

Sub-Committee (3). Revise the specifications for plain and reinforced concrete and for steel reinforcement.

C. P. Richardson, Chairman; R. L. Humphrey, F. P. Sisson, H. A. Cassil, J. J. Yates, T. L. Condron.

The Committee has no revisions to recommend at this time, but expect to further consider this subject next year, when it is hoped a final report can be made.

Sub-Committee (4). Report on different methods of depositing concrete under water.

G. E. Boyd, Chairman; W. M. Ray, A. E. Owen, R. Armour, F. L. Thompson.

Report on this subject is given in Appendix B.

Sub-Committee (5). Report on disintegration of concrete and corrosion of reinforcing materials in connection with the use of concrete in sea water.

J. J. Yates, Chairman; J. E. Smith, R. L. Humphrey.

Report on this subject is given in Appendix C.

Sub-Committee (6). Prepare specifications for slag aggregate.

W. S. Lacher, Chairman; J. K. Conner, W. K. Hatt, Noah Johnson.

Report on this subject is given in Appendix D.

Sub-Committee (7). Report on:

(1) The effect upon the strength and durability of concrete not having a sufficiency of moisture present throughout the period of hardening as compared with concrete fully supplied with moisture.

(2) Methods of providing moisture during the period of hardening.

(3) Remedy for concrete hardened with insufficient moisture.

Report on this subject is given in Appendix E.

COMMITTEE MEETINGS.

In addition to several meetings of the Sub-Committees, two meetings of the General Committee were held in the office of the Association at Chicago, one on December 12, 1918, and the other on January 27, 1919.

SUGGESTIONS FOR FUTURE WORK.

1. Make critical examination of the subject-matter in the Manual and submit definite recommendations for changes.

2. Revise the specifications for plain and reinforced concrete and for steel reinforcement.

3. Report on different methods of depositing concrete under water.

4. Report on disintegration of concrete and corrosion of reinforcing materials in connection with the use of concrete in sea water.

5. An investigation of the distribution of loads through ballast and embankment as affecting the design of masonry structures.

Respectfully submitted,

THE COMMITTEE ON MASONRY.

Appendix A.

CONCRETE CULVERT PIPE.

JOB TUTHILL, Chairman, Sub-Committee.

The subject assigned is the continuation of the work of Sub-Committee No. 5 of 1917, viz., "Report on Designs and Recommend Specifications for Construction of Concrete Culvert Pipe."

General conditions during the year have seriously limited the time the Sub-Committee could devote to committee-work. An endeavor has been made to ascertain a suitable value for the load, or pressure per square foot to be used in designing concrete culvert pipe. While progress has been made, the Sub-Committee feels that further invstigation as to the distribution and transmission of pressures from engine loads and earth fills is necessary before a conclusion can be reached.

A bibliography on this subject is presented as information, with the request that the subject be continued for further study.

BIBLIOGRAPHY ON PRESSURE OR WEIGHT OF EARTH FILL OVER CULVERTS AND PIPES.

1868—Craven, A. W.

Description of a line of large water-mains, laid by the Croton Aqueduct Department of the City of New York and an inquiry into the causes of failure of a few of them. 1868. (In Trans. Amer. Soc. Civil Engrs., v. 1, p. 3.)

Experiments bearing on the question of superincumbent weight on cast-iron pipe.

1878—Slauffer.

Peculiar case of failure in a water main. 1878. (In Trans. Amer. Soc. Civil Engrs., v. 7, p. 14.)

Illustration and description of a hole in the top of a cast-iron water pipe, caused by friction of sand on the outside of the pipe.

1883—Heley, A.

Stability of brick conduits. 1883. (In Jour. Assoc. Engng. Societies, v. 2, p. 123-128.)

Distortion of brick conduits and sewers by external loading; observations from actual construction; illustrated.

1891—Howe, Malverd A.

Some experiments to determine the strength of American vitrified sewer pipe. 1891. (In Jnl. Assoc. Engng. Societies, v. 10, p. 283-303.)

Includes methods and results of making external load tests on pipe.

1897—Barbour, F. A.

Strength of sewer pipe and the actual earth pressure in trenches. 1897. (In Jnl. Assoc. Engng. Soc., v. 19, p. 193-241.)

The trench experiments were designed to ascertain the pressure created on a pipe, culvert, brick sewer or other structure built in a trench, by the superincumbent earth. Details of testing methods and results are given.

1897—Clarke, D. D.
Distortion of riveted pipe by backfilling. 1897. (In Trans. Amer. Soc. Civil Engrs., v. 38, p. 93-114. Paper No. 812.)
Observations on riveted steel pipe laid for the city of Portland, Ore. As the greatest depression was not found uniformly at the points where the pipe was buried the deepest, the conclusion seemed unavoidable that the earth had not been properly tamped around the pipe when the backfilling of the trench was being done. Method of making tests and amount of distortion is given.
Results of tests made in the engineering laboratory: Cast-iron pipe. 1897. (In Technology Quarterly, v. 10, p. 335.)
Summary of tests of cast-iron pipe made by applying loads on the outside.

1898—61-inch cast-iron pipe line. 1898. (In Engng. Rec., v. 39, p. 51.)
Refers to tests made by T. C. Atwood at the Massachusetts Institute of Technology in the spring of 1897; including experiments on the deflection and breaking strength of cast-iron pipes under loads concentrated at the extremities of a diameter.

1900—Coffin, Freeman C.
A few notes on cast-iron pipe. 1900. (In Jnl. New England Water Works Assoc., v. 15, p. 41.)
Holds that aside from unusual pressure, external pressure need not be considered in the design of the thickness of water pipes.

1905—Mohler, O. K., and M. F. Clements.
Pressures on culverts in high embankments. (Letters.) 1905. (In Engng. News, v. 53, p, 420-421, 447.)
Discussion on how the load of a culvert under a high embankment should be computed.

1906—Patton, W. M.
Practical treatise on foundations, p. 118-120. Ed. 2. 1906. New York. Wiley. 549 pp.
Contains data on formulas for computing earth pressure on arch culverts.

1908—Meem, J. C.
Bracing of trenches and tunnels with practical formulas for earth pressures. 1908. (In Trans. Amer. Soc. Civil Engrs., v. 60, p. 1-100. Paper No. 1062.)
Bracing of tunnels made necessary by the pressure of earth on the top and side; experiments on the arching effect of earth pressures.

Talbot, A. N.
Tests of cast-iron and reinforced concrete culvert pipe. 1908. (In Jnl. Western Soc. Engrs., v. 13, p. 376-432.)
Results of tests of pipe by external loading, with discussion on the subject.

1908—Turneaure, F. E., and H. L. Russell.
Public water supplies, p. 553-554. 1908. New York. Wiley. 808 pp.
Contains data on stresses on pipe due to earth filling and other outside forces.

1910—Meem, J. C.
Pressure, resistance and stability of earth. 1910. (In Trans. Amer. Soc. Civil Engrs., v. 70, p. 352-411.)
Experiments on the arching properties of sand and the pressure of earth over brick sewer tunnels and other structures.

1911—Cain, W.
Experiments on retaining walls and pressure on tunnels. 1911. (In Trans. Amer. Soc. Civil Engrs., v. 72, p. 436-474. Paper No. 1192.)
Development of a theory of pressures of earth on the roof and sides of a tunnel lining, based on the grain-bin theory of Janssen, but modified to include the cohesive or shearing resistances of earth in addition to the frictional resistances.
Hazen, A.
Of what thickness shall we make the walls of our large pipe lines? 1911. (In Jour. New England Water Works Assoc., v. 25, p. 29-59.)
Discusses stresses that come from the weight of the backfill; stresses due to the beam action of the pipe; stresses cumulative in places.

1912—Fenkell, G. H.
Report to Board of Water Commissioners of Detroit on breaks in the large water mains. 1912. (In Engng. News, v. 68, p. 762.)
States that the pressure due to earth filling will be felt seriously only for very deep trenches and for large pipe, and in the case of pipes passing under high embankments breakage has been known to occur, but as far as known no trouble has been experienced in Detroit from this cause.
Testing a 66-inch cast-iron pipe. 1912. (In Engng. News, v. 68, p. 824.)
Account of test by outside loading.

1913—Hogg, T. H.
Stresses in circular pipes. 1913. (In Canad. Engr., v. 25, p. 695.)
Gives calculation of stresses due to back fill.
Noble, Alfred, and Silas H. Woodward.
Dams, aqueducts, canals, shafts, tunnels. 1913. (In American Civil Engrs. Pocket Book, p. 1121-1122. Ed. 2. 1913. New York. Wiley. 1473 pp.)
An indication of the nature of the stresses on the outside of tunnel linings.
Marston, A.
The Theory of Loads on Pipes in Ditches and Tests of Cement and Clay Drain Tile and Sewer Pipe. (Bulletin No. 31, Iowa State College of Agriculture and Mechanic Arts Experiment Station, February, 1913.)

1913—Parker, Philip à Morley.
Control of water, p. 446. 1913. New York. Van Nostrand, 1055 pp.
Formula for capacity of pipes to resist unequal earth pressure.

1914—Metcalf, L., and Harrison P. Eddy.
American sewerage practice, v. 1, p. 328-337, 467-512. 1914. New York. McGraw. 3 vols.
Review of experiments and formula for earth pressure on pipe; weight of backfilling; analysis of stresses on masonry arch sections and their relation to external loads on pipe, etc.
Moyer, J. A.
Distribution of vertical soil pressures, dry-sand tests recently completed at the Engineering Experiment Station of the Pennsylvania State College. 1914. (In Engng. Rec., v. 69, p. 608-609.)
Sharp, J.

Some considerations regarding cast-iron and steel pipes, p. 50-72. 1914. London. Longmans. 142 pp.

The nature and extent of external loads to which pipes and hollow cylinders are subjected and must be capable of carrying without danger of collapse.

United States Cast Iron Pipe and Foundry Company.

Cast-iron pipe in all regular sizes, p. 19, 42, 43. 1914. Barlington.

Cites numerous cases where water is conveyed from reservoirs through cast-iron pipes, and method of calculating superimposed load in order to insure safety.

1915—Conant, E. R.

Load tests of concrete pipe. 1915. (In Engng. News, v. 74, p. 556-557.)

Details and results of testing concrete pipes by external loading.

Etcheverry, B. A.

Irrigation practice and engineering; vol. 2, conveyance of water, p. 241-242. 1915. New York. McGraw. 3 vols.

Formula for stress produced by weight of backfill over pipe.

Greathead, J. F.

Soil tests reported and safe underpinning methods in sand described. 1915. (In Engng. Rec., v. 72, p. 631-633.)

Experiments to determine the greatest imposed load a certain sand would safely stand without undue or progressive settlement, also diagram showing distribution of vertical soil pressure.

Moyer, J. A.

Distribution of vertical soil pressures. 1915. (In Engng. Rec., v. 71, p. 330.)

Gives results of experiments made at Pennsylvania State College.

1915—Pile driving destroys a tunnel by clay pressure. 1915. (In Engng. News, v. 74, p. 404-405.)

Nowhere had a pile actually touched the tunnel; the damage was caused wholly by the crowding pressure of the clay.

Schlick, W. J.

Tests of some large reinforced concrete culvert pipe. 1915. (In Concrete Cement Age, v. 6, p. 78-80.)

Pipes were tested to failure with sand boxes on top of pipe; the data show that the safe load for these pipes was somewhat less than one-half the maximum load; however, the series of tests is so limited that no general conclusions can be drawn.

Smith, W. M.

Arch reinforced concrete conduits designad by the theory of least work. 1915. (In Engng. Rec., v. 71, p. 648-653.)

Method of finding earth pressure on arch conduits through earthen embankments.

1916—Enger, Melvin L.

High unit pressures found in experiments on distribution of vertical loading through sand. 1916. (In Engng. Rec., v. 73, p. 106-108.)

Results indicate practically no decrease in maximum intensity of pressure with an increase in bearing area.

Same. Experiments on the distribution of vertical pressure through sand. 1916. (In Railway Rev., v. 58, p. 129-132; Railway Age Gaz., v. 60, p. 321-323.)

Fehr, B. R., and C. R. Thomas.

Results of some tests to determine the distribution of vertical pressure through sand. 1916. (In Engng. Contracting, v. 45, p. 306-309.)

Gives illustration of two types of apparatus used in making tests, also results of tests showing percentages of loads transmitted through sands.

Goldbeck, A. T., and E. B. Smith.

Apparatus for determining soil pressures. 1916. (In Proc. Amer. Soc. Testing Materials, v. 16, p. 310-319.)

Description of method used for testing distribution of pressures through earth fills.

Abstracts. Apparatus for determining soil pressures devised. 1916. (In Engng. Rec., v. 74, p. 48.) Soil pressure measuring device. 1916. (In Engng. and Contracting, v. 46, p. 180-181.) Device to test soil pressure. 1916. (In Engng. News, v. 76, p. 339.)

Miller, M.

Test earth pressures in subway excavation. 1916. (In Engng. Rec., v. 74, p. 291.)

Deflection measurements on timber rangers and computed values of pressures up to 50-foot depths reported.

1916—Sackett, R. L.

Distribution of vertical pressure through sand. (Letter.) 1916. (In Engng. Rec., v. 73, p. 398.)

Discussion on experiments by Melvin L. Enger.

1917—Fehr, R. B.

Distribution of pressure in earth due to concentrated external loading. 1917. (In Engng. Contracting, v. 47, p. 480-482.)

Determination of the distribution of vertical pressures transmitted from an externally applied load through various depths of soil.

Fowler, G. L.

Tests of corrugated culvert pipe under a sand bed. 1917. (In Railway Gaz., v. 26, p. 687-691.)

Investigations of the behavior of culverts under external loading.

Brief abstract. 1917. (In Jnl. Amer. Soc. Mech. Engrs., v. 39, p. 737-738.)

Goldbeck, A. T.

Distribution of pressures through earth fills. 1917. (In Proc. Amer. Soc. for Testing Materials, v. 17, p. 641-661.)

Results of soil-pressure measurements made with the aid of an apparatus already described before this Society. Gives mechanical analysis of sand used in tests and application of results, with discussion.

Abstracts. 1917. (In Good Roads, no. s., v. 14, p. 79-81; Engng. and Contracting, v. 47, p. 589-590.) How are vertical loads distributed through earth-fills? 1917. (In Engng. News, v. 79, p. 116-117.)

Undercrossing wing wall designed to limit base pressure. 1917. (In Engng. News, v. 79, p. 1054-1055.)

Calculations for earth pressure over culvert and method of limiting it.

Marston, A.

The Supporting Strength of Sewer Pipe in Ditches and Methods of Testing, etc. (Bulletin No. 47, Iowa State College of Agriculture and Mechanic Arts Experiment Station, October 10, 1917.)

Appendix B.

DEPOSITING CONCRETE UNDER WATER.

G. E. Boyd, Chairman, Sub-Committee.

This subject was assigned to the Masonry Committee for report at the 1912 convention, and considerable work was done in the way of procuring data from the members and compiling same. Certain conclusions were reached and were adopted by the Association for publication and appear on pp. 293 and 294 of the 1915 edition of the Manual. The Committee feels that these conclusions require revision.

In view of the unsettled conditions during the past season it was not thought desirable to attempt to go over the ground in this way at this time, and this report is presented with the hope that it may promote discussion and result in additional information on means used and results obtained from various methods of depositing concrete under water. The Committee in making its report does so with the recommendation that this subject be again assigned for consideration next year, as it does not feel that any definite conclusions cvan be presented to the Association at this time. There is, however, some data which the Committee believes it is desirable to present to the Association as representing in its opinion the best practices to be followed in depositing concrete under water.

1. In general, where it is possible, the depositing of concrete under water should be avoided, even if such action results in additional expense and possible delay to the work. There is always considerable uncertainty as to the results obtained where concrete is deposited under water, and the Committee believes that where conditions will permit, the additional expense and delay of avoiding it is well warranted.

2. In view of this uncertainty, the need of close supervision by men competent to handle this class of work is of the utmost importance, and concrete should never be deposited under water without experienced supervision. Many failures which have occurred in concrete deposited under water, especially where the structure is located in sea water, can be directly traced either to ignorance or lack of supervision. Frequently the work is done under the supervision of men inexperienced in this class of work rather than to go to the expense of hiring capable men.

Of the methods used, the following seem to give the best results:

1. The concrete is lowered in large buckets having a hinged bottom which sets sufficiently far above the lower edge of the bucket so that it may open freely downward when the bucket reaches the surface upon which the concrete is to be deposited. The top of the bucket is left open, and care is taken to see that the bucket is completely filled before lowering. Efforts made to use a closed top bucket have not been successful, due to the disturbance of the deposited concrete by inrush of water as the bucket is withdrawn.

2. The concrete may be passed through a vertical tube or tremie reaching down to the surface upon which the concrete is to be deposited. In this case the tube should be kept filled with concrete at all times, and the flow should be as nearly continuous as practicable.

3. Jute or cloth bags, from two-thirds to three-fourths filled, have been used successfully. These are placed in a header and stretcher system so that the whole mass is interlocked.

4. Where it is difficult to construct a cofferdam or monolithic work is not required, premolded concrete blocks of large dimensions have been used successfully.

5. A concrete depositing bag made of canvas or other suitable material is a variation of the bucket system. This is filled and the mouth of the bag closed by one turn of a line so looped that a pull on the line will release it. The bag is lowered mouth down to the surface upon which the concrete is to be deposited, and a sharp pull on the line opens the bag and permits the concrete to be deposited. This method does not have the disadvantage of the closed top bucket, since the bag will collapse as the concrete flows out.

There are a number of other methods that have been used, such as depositing directly through the water; depositing a portion of the concrete by one of the above methods in the corner of the form and the balance progressively from wheelbarrows or buckets on the sloping surface, thus gradually filling the form; allowing the concrete to partially set in air and then depositing it in a plastic condition; depositing the concrete dry without the use of water; attempting to grout a foundation composed of riprap or coarse gravel by means of pipes sunk at intervals into the foundation. Although occasionally fair results have been obtained, all of these methods are dangerous, as they almost uniformly result in segregation of the materials or the washing out of the cement.

Depositing With Drop Bottom Buckets.—The drop bottom bucket should be so arranged as not to discharge the load until the bucket reaches the surface upon which the concrete is to be deposited. In lowering the bucket, care should be taken that unnecessary wash is not produced. This may be avoided by slowing up the operation when the bucket is passing through the water. The bucket, when the load is discharged, should be withdrawn slowly until clear of the concrete. In depositing concrete under water by this method it is imperative that the work be continuous and sufficiently rapid to insure bonding of the successive layers. By this means the laitance formed can be brought to the finished surface and later removed after the concrete has hardened. There are a number of other types of buckets, such as the tipping bucket or bottom dumping bucket. The use of all these should be avoided, as they tend to stir up the material and wash out the cement.

Depositing Through Tremie or Vertical Tubes.—This device should be about 14 inches or 16 inches in diameter, made up in sections so that the length may be adjusted to the depth of the water. The joints should

be made flanged and the tube put together with gaskets, in order to avoid leakage of the water into the tube. The top should be flared, in order to receive the concrete properly. The tube should be suspended in such manner that it may be moved laterally as required. The upper end is placed near the level of the working platform, while its lower end rests on the surface upon which the concrete is to be deposited. When the operation starts the tube should be filled in such manner that the concrete is not permitted to drop down through the water. This is accomplished in several ways: One is to place the bottom of the tube in a box, partially filling it with concrete so as to seal the bottom, then lowering the box into the position in which it is to be used. Another method is to plug the tube with cement sacks or other material, which will be forced down as the tube is filled with concrete. In both these methods undesirable material is introduced into the concrete, but if the area to be covered is large this is a matter of minor importance. However, the first deposits from the tube should be kept away from the edge of the work. One requisite of this method is that the tube must at all times be kept filled with concrete and the greatest care exercised to see that the charge is not lost in moving it about the bottom. In case it is lost, the tube should again be filled as at first. One of the disadvantages of this method is that unless the greatest care is exercised, it is almost impossible to avoid losing the charge occasionally. This will depend very largely on the quality of the supervision exercised over the work. Another disadvantage of this method is that the area over which it can be used is limited, and if it is necessary to deposit concrete over a large area a number of tubes should be used. With this method, as with all others, it is desirable that the concrete be deposited continuously from the time the work is started until it is brought above the water level or to the finished surface, which can later be cleaned in the air after the concrete has hardened.

Considerable difference of opinion exists among Engineers as to whether the concrete to be deposited by this method should be made wet or dry. In the first case the concrete is made quite wet and the bottom of the tremie submerged several feet below the surface of the concrete as deposited. The material is allowed to flow out of the tube and seek its own level. In depositing the concrete dry, just sufficient water is used to make it plastic and the concrete is distributed by moving the foot of the tremie over the surface. Good results apparently have been obtained from each of these methods, but the opinion of the Committee is that the dry method is preferable. If the concrete is deposited wet considerable difficulty is encountered in keeping the tremie full and more or less segregation of the materials is bound to occur. It is extremely difficult to move the tube where sufficiently submerged in the concrete to permit the wet concrete being used.

Bagging Method.—While the bagging method insures good concrete and will prevent the formation of laitance, it is open to the objection that a monolithic foundation is not secured. Where, however, the walls

of the foundation formed by the bags will not be exposed to scour, the Committee is of the opinion that the method will give satisfactory results. This method can be used to advantage in sealing the foundations of coffer-dams where it is impracticable to prevent inflow of water through crevices in the bottom. In using this method it must be borne in mind that satisfactory results cannot be obtained unless the bags are carefully placed by hand, and this makes the service of a diver necessary except where placed in very shallow water.

Premolded Concrete Blocks.—Premolded concrete blocks can be used to advantage on a prepared foundation in large structures such as breakwaters, bulkheads, lighthouse foundations, seawalls—any heavy construction where the units can be large enough not to require bonding. The blocks are usually molded in the air in units weighing from 15 to 20 tons, and are deposited in place by the use of derricks.

Materials and Mixing.—Concrete to be deposited in water should be of a richer mixture than when deposited in air, and a leaner mixture than 1-2-4 should not be used. It is the opinion of the Committee that only so much water should be used as will make the concrete of a plastic consistency. Very dry concrete is as undesirable for this purpose as wet concrete. It is the opinion of the Committee that washed gravel of somewhat smaller size than used in the open air concrete will give the best results. This is particularly true where the tremie method is used. The sand should be free from loam and other material, and it is preferable that washed sand be used where possible to obtain it. The aggregate should be capable of producing dense concrete, and it is recommended that tests be made of the materials available to determine the best aggregate for this purpose.

Precautions.—In depositing concrete under water it is imperative that the water be still and that the concrete shall not be exposed to current until it is fully set. This requires that a cofferdam be constructed in such manner as to insure quiet water within the cofferdam. One of the essentials of depositing concrete by any of the above methods is that the concrete be disturbed as little as practicable during the depositing, thus avoiding the formation of laitance. It is impracticable in depositing concrete in water by any method to entirely avoid laitance, and it is therefore necessary on completing a section of concrete to see that the laitance is entirely removed after the concrete has thoroughly set and before the work is resumed. For this reason it is the opinion of the Committee that when a job is started the concrete should be deposited continuously until the finished surface is reached or the concrete brought above the water level so that the laitance may be removed in the air, as it is difficult, if not impracticable, to entirely remove it under water. The formation of horizontal construction joints under water should be avoided.

The ordinary precautions used in depositing concrete in the air are not sufficient when depositing concrete in water, and additional care must

be observed in the latter case to prevent segregation of the materials, the formation of laitance, and to insure proper setting of the mass. Because of the fact that cold retards setting, the concrete should not be deposited in water the temperature of which is low enough to cause serious retardation. Concrete should be thoroughly mixed before it is deposited in water and, therefore, hand mixing should never be permitted, but a batch mixer used.

Appendix C.

REPORT ON DISINTEGRATING OF CONCRETE AND CORROSION OF REINFORCING MATERIALS IN CONNECTION WITH THE USE OF CONCRETE IN SEA WATER.

J. J. YATES, Chairman, Sub-Committee.

Your Committee has confined itself to a careful examination of publications bearing on the subject of concrete and reinforced concrete in sea water. About seventy publications were reviewed, thirty-nine of which have been selected as the best references on the subject, and are herein submitted to the members as information.

The Committee is not prepared to give any conclusions or to make any recommendations on the subject, but requests a reassignment, so that the investigation may be continued.

Action of the Sea on Concrete; by Coignet.
Am. Soc. Civ. Eng., Vol. I, 1871, p. 110.
Statements on the physical and chemical action of the sea on concrete. Concludes that impervious carbonate surface coat is formed, which if not broken will protect the interior concrete from the chemical action of sea water.

The Influence of Sea Water on Mortars; by E. Candlot.
Engineering Record, November, 1897, p. 557.
A digest of experiments and observations made in France over a period of forty years, under conditions adapted closely to practice; also discussion of other experiments.

An Example of the Decomposition of Concrete in Sea Water.
Engineering News, August 27, 1908, p. 238.
Description of the disintegration of dock wall at Charleston Navy Yard, Boston Harbor. (Illustrated.)

Examples of Tidal Injury to Concrete; by Tyrell Slurtzer.
Engineering News, October, 1908, p. 453.
Describes the action of sea water on concrete at Portland, Me.

Effect of Sea Water Upon Concrete; by Edwin Thacher.
Trans. Am. Soc. Civ. Eng., Vol. XLI, December, 1908, p. 42.
Gives a comparison of American and foreign practice.

Reinforced Concrete Pier Construction; by Eugene Klapp (with discussion).
Am. Soc. Civ. Eng., Vol. LXX, 1908, p. 448.
Description of materials used in construction of concrete piers.

Discussion of the Effect of Alkali on Concrete; by G. C. Anderson.
Am. Soc. Civ. Eng., Vol. LXVII, 1910, p. 572. Discussion by R. L.

Humphrey, Vol. LXVII, June, 1910, p. 598.
Described experiments made at Atlantic City, N. J.

Methods of Employing Concrete in Sea Water and Examples of Typical Marine Structures of Concrete; by Chanlar Davis.
Engineering and Contracting, August 31, 1910.

Abstract of paper read at convention of National Association of Cement Users. (Illustrated, 4,000 words.)

Detail Report of Aberthaw Construction Company Tests at the Charleston Navy Yard, Boston.
Cement Age, October, 1911.

Reinforced Concrete in Hydraulic Works; by John Sewell.
Engineering News, Vol. LXVII, May 30, 1912, p. 1029.
Papers No. 30-34 presented to the International Congress held in Philadelphia, Pa., May 23-27, 1912, by Richard L. Humphrey, M. Jacqimot, R. W. Vawdrey, Hungarian State Water Survey, and M. Mederico Perilli, respectively, are reviewed and summarized under the following headings: Durability of concrete; resistance to abrasion; resistance to chemical action; freezing in contact with water and conclusions.

Destruction of Concrete between Tides in Sea Water; by Wm. B. Mackensie.
Engineering News, Vol. LXVIII, July 4, 1912, p. 28.
A discussion of review made by John S. Sewell, published in Engineering News, Vol. LXVII, May 30, 1912, p. 1029, referred to above.

Alkali Action on Concrete, Investigation by the U. S. Reclamation Service; by J. Y. Jewett.
Engineering Magazine, Vol. XLIV, November, 1912, p. 267.
An outline of the method of investigation to be made by the Service.

Abstract from report entitled, "Action of the Salts in Alkali Water on Cement"; by P. H. Bates, A. J. Phillips and R. J. Wig.
Technologic papers of the Bureau of Standards No. 12, November 1, 1912.
The report, which consists of 157 large pages, is covered in a general summary, which includes 16 tentative conclusions. These are based on results of experiments covering three and one-half (3½) years at Atlantic City, N. J.

Action of Alkali and Sea Water on Concrete.
Engineering News, Vol. LXX, July 10, 1913, p. 50.
The U. S. Bureau of Standards Report.

Four Year Test of the Effect of Sea Water on Concrete.
Engineering News, Vol. LXX, November 20, 1913, p. 1023.
A description of the test piles made by the Aberthaw Construction Company after four years' exposure to sea water at Boston, Mass.

Action of Sea Water on Concrete, Six Year Test of 23 Moulded Piles; test conducted by the Aberthaw Construction Company.
Engineering Record, Vol. LXIX, March 21, 1914, p. 344.
Gives large photographs of test piles which show clearly the action of the sea water, with the notes covering each specimen.

Results of Tests to Determine the Action of Sea Water on Concrete.
Engineering and Contracting, Vol. XLI, May 6, 1914, p. 516.
Aberthaw Construction Company tests.

Account of Tests of the Action of Sea Water on Concrete.
Concrete-Cement Age, June, 1914, p. 273.
Report on the test specimens of the Aberthaw Construction Company at Boston, Mass.

Factors Controlling the Durability of Concrete in Sea Water; by F. W. Huber.
Western Engineering, November, 1914.

Explains the chemistry of the action of sea water upon concrete; discusses failures, successful work and remedies proposed to improve cement for this use.

Disintegration of Concrete and Corrosion of Reinforcing Metal.
Am. Ry. Eng. Assoc., Vol. XV, 1914, p. 564.
Includes a discussion of concrete in sea water with conclusion.

Some Experiences with Concrete in the Republic of Panama; by Alex P. Crary.
Engineering News, February 4, 1915.
Gives effect of sea water on concrete. (Illustrated, 2200 words.)

Reinforced Concrete Docks; by H. S. Taft.
Am. Soc. Civ. Eng., Vol. LXXVIII, 1915, p. 1058.
Foreign and American structures, failures, costs and general considerations, with discussion.

Reprint of Report on the Destructive Action of Sea Water on Concrete and Methods of Guarding against it; by W. W. Pagon.
Monthly Journal of the Engineers' Club of Baltimore, April, 1916.
Gives conclusions based on review of subject matter in the Library of the Am. Soc. Civ. Eng.

Characteristics Required of Concrete to Resist Action of Sea Water; by W. W. Pagon.
Engineering and Contracting, May 24, 1916; Engineering Record, Vol. LXXIII, May 27, 1916, p. 702; Concrete, Vol. IX, October, 1916, p. 112.
Conclusions submitted after a careful study of the various articles dealing with the action of sea water on concrete.

Qualities Required of Concrete to Resist the Action of Sea Water; by W. W. Pagon.
Engineering and Mining Journal, July 29, 1916, p. 102.

Bad Effects Resulting from the Use of Salt Water in Reinforced Concrete Structures Built in Tropical Countries; by J. L. Harrison.
Engineering and Contracting, Vol. LXVI, November 22, 1916, p. 443; Engineering News, Vol. LXXVI, November 30, 1916, p. 1047. (Abstract.)
Review of many structures in the Philippine Islands. Concludes that the cause of cracking and failing of reinforced concrete structures is due to use of salt water, porous concrete, chlorine in air, or all combined.

The Effect of the Use of Salt Water for Gaging Concrete on the Life of the Reinforcing Steel Embedded therein; by J. L. Harrison.
Monthly Journal of the Engineering Club of Baltimore, December, 1916.
Concludes that the gaging of concrete with salt water in the Philippine Islands was dangerous. (Illustrations.)

Tests of Concrete Specimens in Sea Water at Boston Navy Yard; by R. E. Bakenhus.
Transactions Am. Soc. Civ. Eng., Vol. LXXXI, December, 1917, p. 645.
A report of the behavior of the twenty-four test pieces made by the Aberthaw Construction Company after having been exposed to the sea water for seven years. Also discussion. (Illustrated, 2000 words.)

The Effect of Sea Water on Some of the Concrete Structures in the Philippine Islands; by J. L. Harrison.
Engineering and Contracting, June 27, 1917.
Concludes by chemical analysis of specimens taken from various structures in the Philippine Islands that chemical action does take place in tidal tropical water. (Illustrated, 2000 words.)

Public Works of the Navy, Bulletin 27, July, 1917; Bulletin 28, October, 1917.

Report submitted by the Bureau of Standards to the Bureau of Yards and Docks of the Navy Department, covering investigation of the action of sea water on concrete.

What Is the Trouble with Concrete in Sea Water; by Rudolph J. Wig and Lewis R. Ferguson.

Engineering News Record, Vol. LXXIX, September 20, 1917, p. 532.

First of a series of five papers on the deterioration of concrete in sea water. Reports are based on an examination of 146 structures in the United States, Canada, Cuba and South America. (Illustrated, 2000 words.)

Plain Concrete in Sea Water Must Be Protected against Abrasion; by Rudolph J. Wig and Lewis R. Ferguson.

Engineering News Record, Vol. LXXIX, October 4, 1917, p. 641.

The second of a series of five articles.

Reinforced Concrete in Sea Water Fails from Corroded Steel; by Rudolph J. Wig and Lewis R. Ferguson.

Engineering News Record, Vol. LXXIX, October 11, 1917, p. 689.

The third of a series of five articles stating that "Percolation of salt water or salt air to reinforcing steel causes rusting with subsequent expansion and resulting failure of structure; remedies are difficult to find." (Illustrated.)

Selection of Materials for Sea Water Concrete; by R. J. Wig and Lewis R. Ferguson.

Engineering News Record, Vol. LXXIX, October 18, 1917, p. 737.

The fourth of a series of five articles, stating that "Any standard Portland cement may be considered safe as may also sea water gaging; great care should be exercised in choosing aggregate." (Illustrated.)

Good Workmanship Necessary to Make Sea Water Concrete Safe; by R. J. Wig and Lewis R. Ferguson.

Engineering News Record, Vol. LXXIX, October 25, 1917, p. 794.

The last of a series of five articles stating that "Correct proportions, judicious use of water, tight forms, a good contractor and efficient inspection are needed to bring concrete to proper condition to resist sea water action." (Illustrated.)

Spalling of Reinforced Concrete in Moist Locations; by F. E. Turneaure.

Engineering News Record, Vol. LXXX, January 3, 1918, p. 46.

States that "Spalling is due to alternate wetting and drying of concrete." (Illustrated.)

Comment on the Behavior of Sea Water Concrete.

Engineering News Record, Vol. LXXX, February 7, 1918, p. 264, and March 21, 1918, p. 575.

A discussion of the articles on concrete in sea water which were written by R. J. Wig and Lewis R. Ferguson.

Are Spirally Wound Concrete Piles Safe in Sea Water; by A. C. Chenowith.

Engineering News Record, Vol. LXXX, May 9, 1918, p. 926.

A short discussion of Chenowith piles with reference to the articles published in Engineering News Record during September and October, 1917.

Effect of Sea Water on Concrete.
Concrete, Vol. XIII, July, 1918, p. 35.
Points out the need for careful determination to provide against the probable action of sea water on concrete hulls of ships.

Reinforced Concrete in Harbor Works; by A. F. Dyer.
Canadian Engineer, Vol. XXXV, September 26, 1918, No. 13, p. 277.
Discussion of experience with reinforced concrete in harbor work at Halifax, N. S., extending over a period of several years.

Appendix D.

PREPARE SPECIFICATIONS FOR SLAG AGGREGATE.

W. S. Lacher, Chairman, Sub-Committee.

After a study of the data available on the properties of slag and of specifications for slag as an aggregate in concrete, your Committee does not feel warranted in submitting a specification for adoption by the Association. The following discussion of this subject is submitted as information. This applies to the use of slag as the *coarse* aggregate only.

The Committee believes that the general requirements for coarse aggregates for use in concrete as specified in paragraph 4, page 282, of the Manual, may be applied to blast furnace slag without modification.

Further requirements for slag in current specifications examined cover such matters as origin, method of cooling, age, weight, strength and chemical limitations. At the end of this report a table is presented which lists the requirements of ten specifications for slag to be used in concrete and which demonstrates a marked lack of uniformity. We offer the following comments:

As to origin, only two specifications definitely called for blast furnace slag, all others read so as to permit the products of the steel furnace as well as the blast furnace.

Air cooling is general and represents the type of material desired. This can be required without causing any commercial difficulties. When it comes to the matter of age or time of seasoning, the case is not so clear and the requirements vary. Some specifications demand a year's seasoning, others permit the use of the material after two or three weeks. The necessity for this depends on the nature of the slag. According to Sanford E. Thompson, a limestone slag (one containing only 1 to 2 per cent. of magnesia) is not stable until seasoned for considerable periods, while a magnesia slag (one containing 4 per cent. or more of magnesia) is commonly used within two or three weeks after banking, as no chemical change is apparent on exposure.

The weight is the most definite requirement and concerning which there is the greatest uniformity. Seventy pounds per cu. ft. would seem to be a conservative yet reasonable figure.

Strength requirements are considered as impractical and without adequate precedent. Those discovered apply only to materials to be used in pavements where resistance to abrasion or surface impact is important.

Chemical limitations are placed in specifications for slag presumably to exclude materials containing unstable compounds or elements of a disintegrating or corrosive nature. The content of sulphur receives the widest attention in this regard and the limitation has been variously stated at from 1 to 2 per cent. where it is covered in the specification.

The presence of unslaked lime seems to be of more vital importance since the presence of this material would obviously tend toward unsound-

ness of the slag on exposure to moisture unless neutralized by acid ingredients. It is because of this that some specifications place the limitations on the lime content and specify a minimum amount of silica to insure that enough of the SiO_2 radical shall be present to stabilize the CaO. As some users of slag are of the opinion that the seasoning of the material in a bank exposed to the weather would insure the elimination of any free lime and as there appear to be no test data available tending to demonstrate the adequacy and efficacy of these chemical requirements for sulphur, lime or silica, the Committee does not feel qualified to make any definite recommendation in this regard.

In using slag in concrete it is necessary to include a requirement in the specification for the concrete that will insure proper proportions. Very strong concrete may be made with slag if the proportion of cement and fine and coarse aggregates are such as to provide high density, but owing to the porous nature of most slags, somewhat larger quantities of cement and fine aggregate will be required to obtain the desired density than is the case of most ordinary materials used as coarse aggregates.

Specification Requirements for Slag.

Authority	Strength	Origin	Air Cooled	Age	Weight lb. per cu. ft.	Sulphur Not Over	Lime, Not Over	Silica, Lot Less Than
New York Central	....	Blast Furnace	Yes	2 mo.	70	1.7%*	48%	33⅓%
Sanford E. Thompson	....	....	Yes	....	65†	1.7%	48%	32%
Central of Georgia	....	....	....	1 yr.	....	....	....	....
Viaduct Cuyahoga County, Ohio	‡	....	....	....	74	....	....	....
Bldg. Spec. Philadelphia	....	Blast Furnace	Yes	....	75	1.3%	....	....
Ohio State Highways A	Toughness not less than five	....	....	....	70	1.5%	45%	32%
Ohio State Highways B	Toughness not less than five	....	....	....	65	2.0%	45%	32%
Ohio State Highways C	....	....	....	....	....	2.0%	45%	30%
Youngstown City Engineer	....	....	Yes	Lime slag 3 months Mag. slag less	68	....	....	....
U. S. Department of Agriculture	....	....	....	....	70	....	....	....

*No free sulphur, chemical analysis every 2,000 cu. yd.
†After shaking to refusal.
‡Abrasion loss not more than ten. Factor of hardness not less than twelve. Factor of toughness not less than six.

A series of tests made by Professor D. A. Abrams at the Structural Materials Research Laboratory, Lewis Institute, Chicago (not heretofore published) show the importance both on the wearing qualities and strength of proper storage during the early hardening period. The results of these tests, which are made a part of this report, indicate that with small speci-

mens a few days' moisture is helpful to the strength and wearing qualities, while provision for moisture for several weeks will produce results almost equal to those which would be obtained with continuous favorable storage conditions.

While the results on small specimens only approximate the results to be expected where large masses of concrete are used, it is not unreasonable to assume that particularly where the concrete is to be used as a wearing surface, great improvement in the strength and wearing qualities can be obtained by providing moisture to the hardening concrete for several weeks after the concrete is mixed and placed. The usual specifications for concrete roads provide that concrete shall be covered with earth or other similar material and kept moist for two weeks. Floor specifications are also being changed to provide for similar protection. The better floor contractors now cover the newly laid floor with sand and keep the floor sprinkled for from several days to two weeks. A marked improvement in wearing qualities is noticeable. In mass concrete, while provision for moisture is desirable and should be encouraged where practicable, it is not absolutely imperative as mass rather than high strength is sought.

In all reinforced concrete structures, however, some provision should be made to prevent the rapid drying out of the concrete, which almost invariably occurs during the summer months. Many contractors have observed that concrete placed in the early spring and late fall, and many claim in the winter, shows far more satisfactory results than concrete placed in middle summer. This difference, no doubt, arises from failure to provide plenty of moisture to the rapidly hardening concrete in summer. All concrete should be protected from the direct rays of the sun and unless the expense is absolutely prohibitive, sprinkled for from several days to several weeks, depending upon the character of structure.

EFFECT OF QUANTITY OF MIXING WATER AND CURING CONDITIONS ON THE STRENGTH AND WEAR OF CONCRETE.

By Duff A. Abrams.*

Introduction.

The necessity for careful restriction on the quantity of mixing water used in concrete, and the importance of proper curing conditions during the period of setting and hardening are not generally appreciated by engineers and contractors doing concrete work. In view of the widespread use of concrete in the construction of pavements, floors, loading platforms, and in other places requiring high strength and resistance to abrasion, it seemed desirable to carry out an experimental study which would bring out the effect of water content and curing conditions on the compressive strength and the wearing resistance of concrete, and the relation between these two properties.

These tests were made as a part of the experimental studies of the properties of concrete and concrete materials, being carried out through the co-operation of Lewis Institute and the Portland Cement Association at the Structural Materials Research Laboratory, Lewis Institute, Chicago.

This series comprised compression tests of 120 6 x 12-inch cylinders and wear tests on 300 blocks, 8 inches square and 5 inches in thickness. A 1-4 mix was used throughout, that is, 1 volume cement and 4 volumes mixed aggregate. This mix is about the same as the 1-1½-3 or 1-2-3 mixes generally used for concrete which is to withstand high stresses or to form the wearing surface of pavements. Most of the tests were made on sand and pebble aggregates. One group was repeated with crushed limestone as coarse aggregate.

Concrete of six different consistencies was used, each being stored under four different conditions:

(1) Damp sand 4 months, tested damp.
(2) Damp sand 21 days, air 99 days.
(3) Damp sand 3 days, air 117 days.
(4) Air of laboratory for entire curing period of 4 months.

Parallel tests were made throughout on compression and wear. All tests were made at the age of 4 months.

The wear blocks were tested in the Talbot-Jones rattler by the same methods that were used in other tests carried out in this laboratory.†

*Professor in Charge of Structural Materials Research Laboratory, Lewis Institute, Chicago.

†See "A Method of Making Wear Tests of Concrete" by D. A. Abrams, Proc. American Society for Testing Materials, Part II, 1916; also "Effect of Time of Mixing on the Strength and Wear of Concrete," by D. A. Abrams, Proc. American Concrete Institute, 1918.

Acknowledgment is due to the Chicago Gravel Company, Chicago, for their courtesy in furnishing the sand and pebble aggregate used in these tests, and to Dolese & Shepard, Chicago, for the crushed limestone.

MATERIALS.

The Portland cement used in these tests consisted of a mixture of equal parts of four brands purchased in the Chicago market. The brands were thoroughly mixed by placing one sack of each in a concrete mixer and running for about one minute. Complete tests of the cement are given in Table 1.

The aggregates consisted of sand and pebbles from the Chicago Gravel Company's plant near Elgin, Ill., and crushed limestone from Dolese & Shepard Company's quarry. Before using, the sand was screened through a No. 4 sieve. All material coarser than this size was rejected. The sand was used without further screening, but care was taken to see that the material in the bin was thoroughly mixed so that it was uniform throughout the series. Pebbles and crushed limestone were screened to three different sizes (No. 4-3/8, 3/8-3/4, and 3/4-1 1/4 inches) and recombined in definite proportions for each batch, as shown by the sieve analyses in Table 2.

The water was from the city water supply obtained from Lake Michigan.

The weights per cubic foot of aggregates were determined by means of machined, cast-iron measures having capacities of 1/6 and 1/2 cubic foot. The 1/6 cubic foot measure was used for the sand and the 1/2 cubic foot for the coarse aggregates and the mixed aggregates. The inside diameter of each measure is equal to the depth. The test was made by filling the measure about one-third full and puddling with a 5/8-inch steel bar pointed at the lower end. Filling and puddling were continued in like manner until the measure was full. After striking off with a straight-edge the weight was determined. This is the method recommended by Committee C-9 on Concrete of the American Society for Testing Materials, but the method has not yet been standardized by the Society.

The absorption of the aggregate was determined as follows:

The sand was dried to constant weight and cooled to room temperature in a desiccator. A 500-g. sample was placed in a 500-cc. volumetric flask and the volume of water necessary to fill to mark carefully measured. At frequent intervals the flask was filled to mark. The zero volume was obtained in the same manner, except that the sand was coated with kerosene to prevent absorption of water. This is an adaptation of Rea's method for determining specific gravity of fine aggregates.*

The coarse aggregate was dried to constant weight, cooled to room temperature and weighed, then immersed in water at room temperature.

*See "Apparent Specific Gravity of Non-Homogeneous Fine Aggregates," by A. S. Rea, Proc. A. S. T. M., Part II, 1917.

At frequent intervals it was removed from the water, quickly surface-dried with a towel and weighed. Our experience with these methods indicates that the absorption at about 3 hours gives the best results in estimating the quantity of water necessary for concrete mixes.

Proportioning and Mixing Concrete.

In all the tests included in this report the concrete consisted of a 1-4 mix by volume; that is, 1 volume of cement to 4 volumes of mixed aggregate, considering 94 pounds of cement as 1 cubic foot. This mix is equivalent to the 1-1½-3 or 1-2-3 mixes generally used for one-course concrete road construction. The exact equivalent of our 1-4 mix when expressed in the customary manner will depend on the size and grading of the aggregate.

The concrete was mixed by hand in the manner regularly followed in making such tests in this laboratory. Each specimen was made from a separate batch of about ⅙ cubic foot, which was proportioned separately and mixed with a bricklayer's trowel in a shallow metal pan. This method leaves no uncertainty as to the exact quantities of materials in each specimen.

The term "consistency" as used in this report refers to the plasticity of the concrete; that is, the relative and not the actual quantity of mixing water. It has been found convenient to express the quantity of water used in the concrete in terms of the volume of cement. This so-called water-ratio has been shown to be the best criterion of the strength of the concrete.

The consistency which we have called "normal" (relative consistency = 1.00) is of such a plasticity that a 6 x 12-inch cylinder of 1-4 concrete will "slump" ½ to 1 inch upon removal of the metal form by a steady, upward pull immediately after molding the specimen. Concrete of relative consistency of 1.10 will show a slump of 5 to 6 inches; 1.25, a slump of 8 to 9 inches.

Test Pieces.

This report covers compression tests of 6 x 12-inch concrete cylinders and wear tests on concrete blocks 8 inches square and 5 inches in thickness.

The 6 x 12-inch cylinders were molded in metal forms made of 12-inch lengths of 6-inch inside diameter cold drawn steel tubing, which had been split along one element by means of a thin slotter. The form was closed by a circumferential band. Each form stood on a machined, cast-iron base plate. A thin sheet of paraffined tissue paper was placed between the base plate and the cylinder form.

In molding the cylinder the form was filled about one-third full and the concrete puddled with a ¾-inch steel bar about 21 inches long. Filling and puddling were continued until the form was full. The top was

leveled off with a bricklayer's trowel. About 3 to 4 hours after molding, a thin layer of neat cement paste (which was mixed at the same time or before the concrete) was spread over the top of the cylinder. A piece of plate glass and a sheet of paraffined paper were used to form a cap, which made a smooth, square end for loading. The glass remained in place until the form was removed. This method of capping is much better than setting the specimens in plaster of paris or a cement-plaster mixture immediately before testing. It has the following advantages:

(1) The cap is just as strong and stiff as the concrete and forms an integral part of the specimen.
(2) The time and labor required is a small part of that necessary with the plaster method.
(3) The plate glass prevents evaporation of water during the period the concrete is in the form.
(4) The cylinder is ready for test at any time without further preparation.

The metal forms for the wear blocks were made in gangs of three. The form was set on a sheet of building paper laid directly on the concrete floor. The form was filled before puddling. The top was leveled off with a trowel. After a period of one to two hours the tops of the blocks were finished by hand with a wood float. Instead of capping, the blocks were covered with a sheet of wet building paper and about 3 inches of damp sand. This method prevented loss of water while the blocks were in the forms.

All test pieces were allowed to remain in the metal forms over night. Upon removal of the forms they were stored in the manner indicated in Table 4. Two cylinders and five wear blocks were made in each group before the duplicate sets were begun. The duplicate sets were made two to four weeks after the first.

Methods of Testing.

The compression tests of concrete were made in a 200,000-pound Olsen universal testing machine. A spherical bearing block was used on top of the cylinders.

Wear tests of concrete were made in the Talbot-Jones rattler. The test pieces consist of blocks 8 inches square and 5 inches in thickness. The blocks are arranged around the perimeter of the drum of the rattler, as shown in Fig. 1. Ten blocks constitute a test set. The ten-side polygon formed by the test blocks presents at nearly continuous surface. The outside diameter of the polygon thus formed is 36 inches and the inside diameter 26 inches. During the test the front of the chamber is closed by means of a light steel plate. The abrasive charge consists of 200 pounds of cast-iron balls (about 133 1⅞ inches and 10 3¾ inches in diameter). These balls conform to the requirements for the standard rattler test of paving brick of the American Society for Testing Materials.

The test consists of exposing the inner faces of the concrete blocks to the wearing action of the charge for 1800 revolutions at the rate of 30 revolutions per minute. The machine was run for 900 revolutions in one direction, then reversed. Two sets of blocks are tested at once in the machine now in use. Each block was weighed upon removal from the form, upon removal from the damp sand, immediately before and after testing. The loss in weight during the test is used as a measure

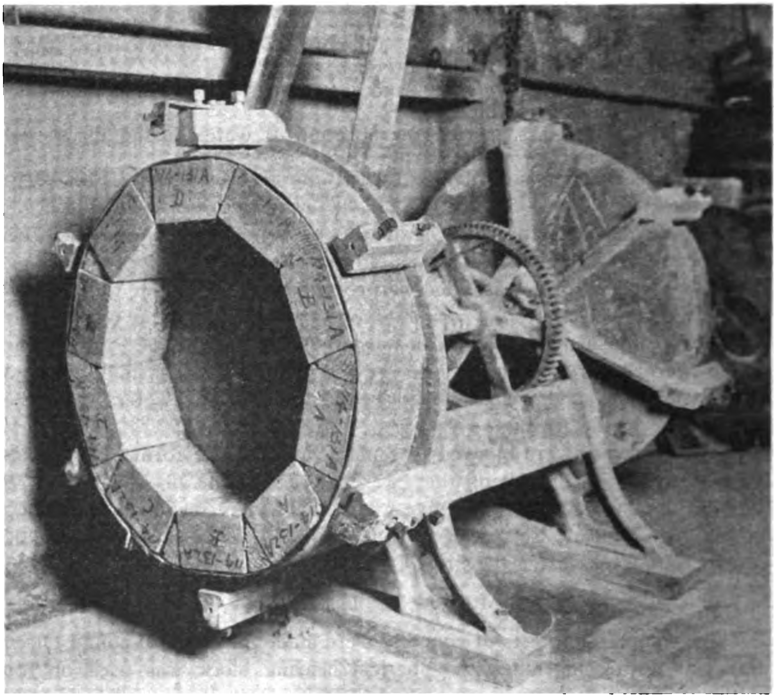


FIG. 1—TALBOT-JONES RATTLER WITH CONCRETE WEAR BLOCKS IN PLACE. Wear tests were made on blocks 8 inches square, 5 inches thick.

of the wear. This loss is reduced to an equivalent depth of wear in inches.

Absorption tests were made on two wear blocks from each set of 10. The tests were made when the blocks were about one year old, after having been stored in the open air in the laboratory during the period following the wear test. The blocks were dried to approximately constant weight on a steam radiator, weighed and immersed in water at room temperature. At various intervals they were removed from the water,

allowed to drain for about 5 minutes and weighed. The gain in weight was reduced to an equivalent volume of absorbed water.

DISCUSSION OF TESTS.

The tests included in this report consisted of compression tests of 120 6 x 12-inch concrete cylinders and 300 wear tests of 8 x 8 x 5-inch blocks, as well as miscellaneous tests of cement and aggregate. A 1-4 mix was used throughout, with aggregate graded up to $1\frac{1}{4}$ inches. In

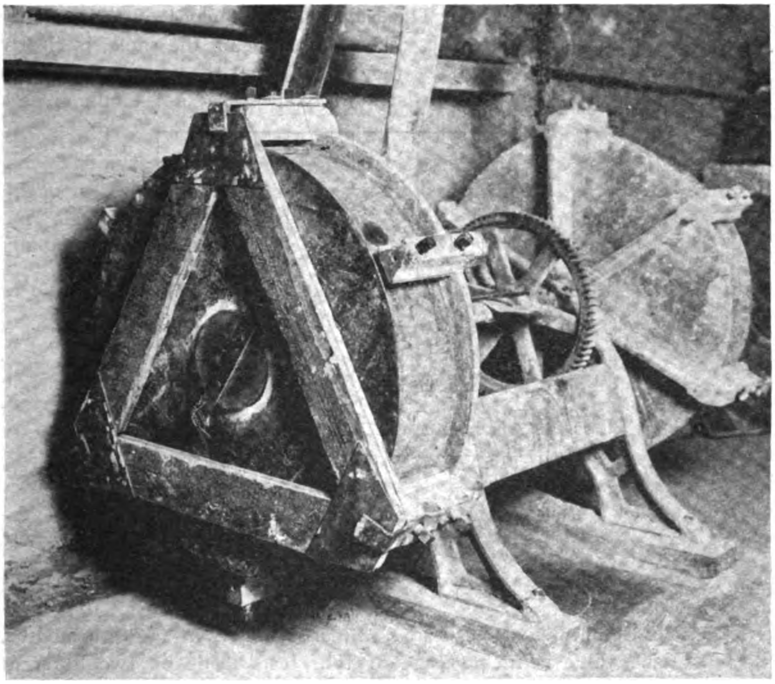


FIG. 2—TALBOT-JONES RATTLER WITH HEAD CLOSED READY FOR TEST.
The machine was operated for 1800 revolutions at 30 revolutions per minute. The abrasive charge consisted of 200 pounds of cast-iron balls.

general the coarse aggregate was pebbles; in one group of tests a crushed limestone was used. This mix is approximately the same as that generally used in one-course concrete road construction. Four different curing conditions were used for pebble aggregate as follows:

(1) Damp sand 4 months, tested damp.
(2) Damp sand 21 days, air 99 days.
(3) Damp sand 3 days, air 117 days.
(4) Air of laboratory for entire curing period of 4 months.

Group (1) was repeated, using crushed limestone as coarse aggregate. All compression and wear tests were made at age of 4 months. Average values from the strength and wear tests are given in Table 4.

Effect of Quantity of Mixing Water on the Strength of Concrete.

Fig. 3 gives the results of the tests on the effect of quantity of mixing water on the compressive strength of concrete. A separate curve has been drawn for each curing condition. An average curve from these tests will be found in Fig. 8. The remarkable influence of the quantity of mixing water on the strength, other factors being the same, is clearly shown by these curves. It will be remembered that the consistency which we have called 1.00 (normal consistency) is such that a 1-4 mix gives a

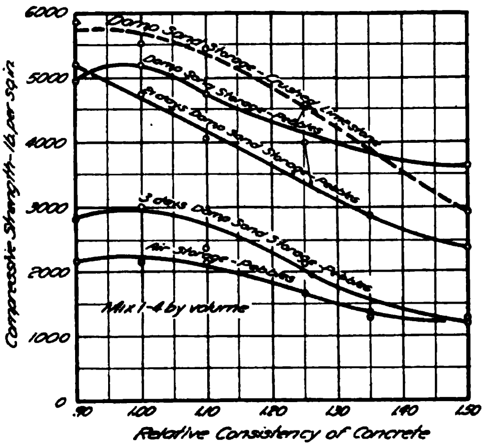


Fig. 3—Effect of Quantity of Mixing Water on the Strength of Concrete.

Compression tests of 6 x 12-inch cylinders at age of 4 months. Each value is the average of four tests made on two different days. Same data as in Fig. 5.

slump of ½ to 1 inch when the form is slipped off the freshly molded cylinder. A consistency of .90 contains 90 per cent. of the amount of water required for normal consistency; a consistency of 1.50 contains 1½ times the quantity of water used in the normal consistency concrete, etc. The normal consistency concrete may be characterized as plastic; the .90 is somewhat dry; the 1.50 quite wet, but contains much less water than the "sloppy" mixes frequently seen in reinforced concrete work.

It will be noted that there is a rapid falling-off in strength as the water content is increased from normal consistency. With a consistency of 1.25 the strength is reduced to about 75 per cent. of the highest; with a consistency of 1.50 the strength is only one-half that which may be

obtained with the same cement content. For wetter mixes the strength would be still further reduced.

In general it will not be feasible to use concrete of a consistency which will give maximum strength, since it is somewhat too stiff for satisfactory workability. In concrete road work where hand finishing is used the concrete must be mixed to a consistency varying from 1.10 to 1.15. In other words, we must sacrifice a portion of the possible strength of the concrete in order to secure a workable mix. This consistency will give a slump of 5 to 7 inches. If machine finishing is employed the concrete can be mixed to a consistency corresponding closely to maximum strength. In reinforced concrete work there is in general little excuse for using mixes wetter than 1.25 consistency, corresponding to a slump of 8 to 9 inches.

The average curves in Fig. 8 have been platted in terms of the water-ratio instead of the relative consistencies, although relative consistencies are also shown. The water-ratio is the ratio by volume of water to cement in the batch.

Further Discussion of Effect of Quantity of Mixing Water on the Strength of Concrete.

Many series of tests made in this laboratory have fully established the fundamental importance of the quantity of mixing water on the strength of concrete.

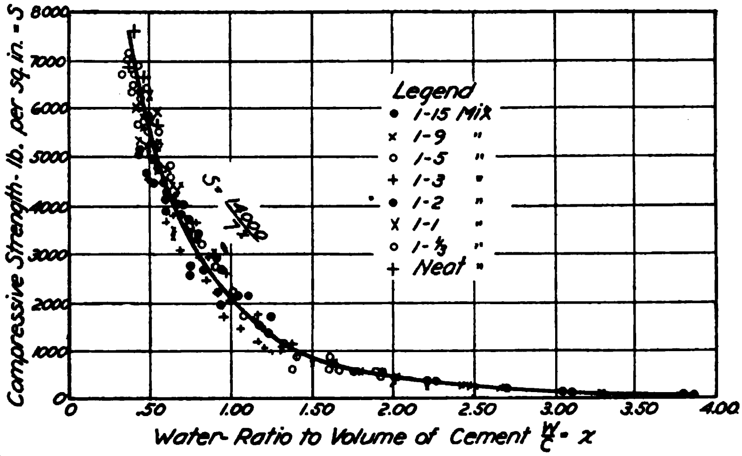


FIG. 4—Effect of Quantity of Mixing Water on the Strength of Concrete.

Compression tests of 6 x 12-inch cylinders at age of 28 days. Each value is the average from five tests. Details of tests not given in this report.

Fig. 4 gives the average values from a series of tests of this kind in which the compressive strength is platted against the water-ratio of

the concrete. In this series the mixes ranged from 1-15 up to neat cement. The consistencies were varied over a wide range. The size of the aggregate ranged from a very fine sand to a coarse concrete aggregate, for all combinations of mix and consistency. Further details of these tests are not given in this report.

In the figure distinguishing marks were used for each mix, but no distinction was made between aggregates of different sizes or concretes of different consistencies. When the compressive strength is platted against the water content in this way a smooth curve is obtained due to the overlapping of the points for different mixes, consistencies, etc. Values from the dry concretes have been omitted from the diagram; if these were used we should obtain a series of curves dropping downward to the left from the curve shown. It is seen at once that the size and grading of the aggregate and the quantity of cement are no longer of any importance except in so far as these factors influence the quantity of mixing water required to produce a workable concrete. This gives an entirely new conception of the function of the constituent materials entering into a concrete mixture.

The equation of the curve in Fig. 4 is of the form

$$S = \frac{A}{B^x}$$

where S is the compressive strength of the concrete and x is the ratio of the volume of water to volume of cement in the batch (water-ratio). A and B are constants whose values depend on the quality of the cement used and on other conditions of the test.

The values of the constants in these tests are shown on the diagram. This equation expresses the law of the strength of concrete so far as variations in the proportions of materials are concerned. It is seen that for given concrete materials the strength depends on only one factor—the water-ratio. Equations which have been proposed for this purpose in the past contain terms which take into account such factors as quantity of cement, proportions of fine and coarse aggregate, voids in aggregate, etc., but they have uniformly omitted the only item which is of any importance; that is, the water. The relation given above holds so long as the concrete is not too dry for maximum strength, and the aggregate not too coarse for a given quantity of cement; in other words, so long as we have a workable concrete.

The strength of the concrete responds to changes in water, regardless of the reason for these changes. The water-ratio may be changed due to any of the following causes:

(1) Change in mix (cement content).
(2) Change in size or grading of aggregate.
(3) Change in relative consistency.
(4) Any combination of (1) to (3).

In certain instances a 1-9 mix is as strong as a 1-2 mix, depending only on water content. It should not be concluded that these tests indi-

cate that lean mixes can be substituted for richer ones without limit. We are always limited by the necessity of using sufficient water to secure a workable mix. So in the case of the grading of aggregates. The workability of the mix will in all cases dictate the minimum quantity of water that can be used. The importance of the workability factor in concrete is therefore brought out in its true relation.

The problem of designing concrete mixes resolves itself into this:

To produce a workable concrete with a given water-ratio using a minimum of cement; or the converse, to produce a workable concrete which has the lowest water-ratio for a given quantity of cement. The methods of securing the best grading of aggregate and the use of the driest practicable concrete are seen to be only devices for accomplishing the above-mentioned results. A forthcoming Bulletin on the "Design of Concrete Mixtures" will give further details of the principles underlying the proportioning of concrete, and discuss their application to practical problems.

The influence of the water-ratio of concrete on its strength will be shown by the following considerations: One pint more water than necessary to produce a plastic concrete in a 1-4 mix reduces the strength to

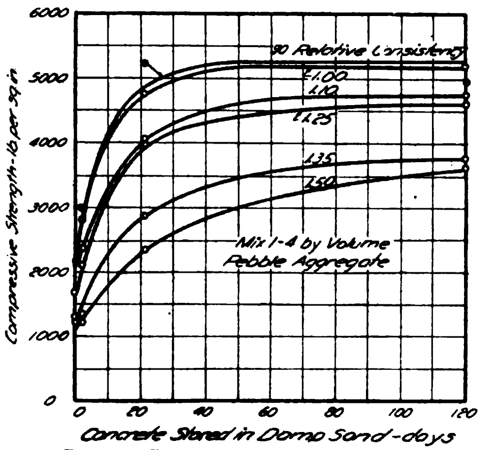


FIG. 5—EFFECT OF CURING CONDITIONS ON THE COMPRESSIVE STRENGTH OF CONCRETE.

Compression tests of 6 x 12-inch cylinders at age of 4 months. Each value is the average of four tests made on two different days. Same data as in Fig. 4.

the same extent as if we should omit 2 to 3 pounds of cement from a one-bag batch.

Our studies give us an entirely new conception of the function performed by the various constituent materials. The use of a coarse, well-graded aggregate results in no gain in strength unless we take advantage

of the fact that the amount of water necessary to produce a plastic mix can thus be reduced. In a similar way we may say that the use of more cement in a batch does not produce any beneficial effect, except from the fact that a plastic, workable mix can be produced with relatively less water.

The reason a rich mixture gives a higher strength than a lean one is not that more cement is used, but because the concrete can be mixed (and usually is mixed) with a lower water-ratio in the case of the richer mixtures than for the lean ones. If advantage is not taken of the fact that in a rich mix relatively less water can be used, no benefit will be gained as compared with a leaner mix. In all this discussion the quantity of water is compared with the quantity of cement in the batch (cubic feet of water to one sack of cement) and not to the weight of dry materials or of the concrete, as is generally done.

For the other curves showing the strength water-ratio relation, see paper on "Time of Mixing Concrete," referred to above.

Effect of Quantity of Mixing Water on the Wear of Concrete.

Figs. 6 and 8 give the results of tests to determine the effect of quantity of mixing water on the wear of concrete. It will be noted that

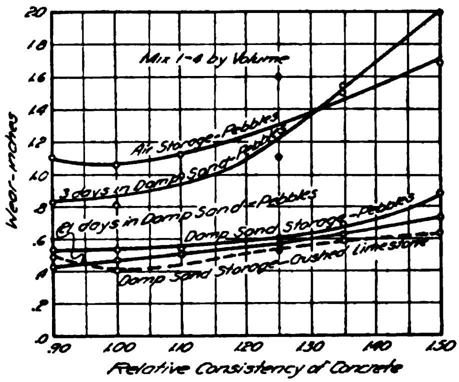


FIG. 6—EFFECT OF QUANTITY OF MIXING WATER ON THE WEAR OF CONCRETE.

Wear tests of 8 x 8 x 5-inch blocks at age of 4 months. Each value is the average of 10 blocks made on two different days. Same data as in Fig. 7.

the depth of wear is expressed in inches. The wear-water-ratio relation is just opposite to that found in the strength tests; in other words, a high strength is accompanied by low wear, and vice versa. If the wear curve in Fig. 8 were inverted we should have almost a duplicate of the strength curve. In general, the lowest wear is found at about the same

water-ratio as the highest strength. The average curves (Fig. 8) show that maximum strength and minimum wear come at a consistency of about .95, or a water-ratio of about .70. It should be pointed out that for other mixes the best results would probably be found at about the same relative consistency, but at a different water-ratio. For a given consistency the water-ratio is higher for lean mixes and lower for rich mixes.

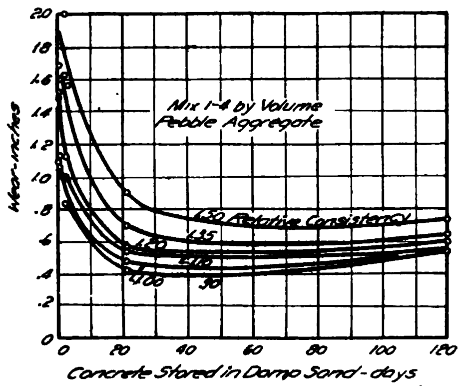


FIG. 7—EFFECT OF CURING CONDITIONS ON THE WEAR OF CONCRETE.
Wear tests of 8 x 8 x 5-inch blocks at age of 4 months. Each value is the average of 10 blocks made on two different days. Same data as in Fig. 6.

WATER REQUIRED FOR CONCRETE MIXES.

Since the quantity of mixing water exerts such an important influence on the strength and other properties of concrete, it will be of interest to examine the factors which influence the amount of water required for satisfactory results. The function of water in concrete is twofold:

(1) To supply the water necessary for hydration of the cement.

(2) To produce a plastic mixture.

While the exact quantity of water required under (1) has not been determined except in certain instances, it is generally agreed that the quantity used in concrete is greatly in excess of that necessary for hydration of the cement. The bulk of the water in concrete is used in order to produce a plastic or workable mix. The exact quantity required for this purpose depends on the materials used, nature of the work, and methods of handling and finishing.

It is, in general, impracticable to state in definite quantities the amount of water which should be used, since this depends on many different factors, such as the following:

(1) The relative consistency which must be used, which is dictated by the nature of the work.
(2) The normal consistency of the cement.
(3) The quantity of cement.
(4) The size and grading of the aggregate.
(5) The absorption of the aggregate.
(6) The moisture content of the aggregate.
(7) Admixtures which may be used.

A water formula has been developed which takes into account all these elements; however, since it involves certain factors which cannot be covered in this report, a discussion of this phase of the work will be deferred.

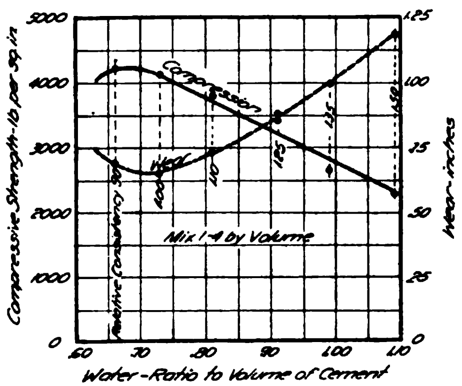


FIG. 8—EFFECT OF QUANTITY OF MIXING WATER ON THE STRENGTH AND WEAR OF CONCRETE.

Average curves from Figs. 4 and 6. The quantity of mixing water is expressed as a ratio to the volume of cement in the batch. Each value for compression is the average of 20 tests (four curing conditions). Each value for wear is the average of 50 tests (four curing conditions). In interpreting this diagram it should be borne in mind that we have averaged the four storage conditions described in Table 4. For best curing conditions concrete will show much less wear than any indicated by this curve.

The quantity of water which affects the water-ratio as given in Fig. 8 is only such a part of the whole as affects the cement. In other words, the water which is absorbed by the aggregate is not considered as influencing the water-ratio. This makes it plain that the absorption of the aggregate must be taken into account if concretes from widely different aggregates are being compared. Many serious errors have been made

in drawing conclusions from tests, due to failure to take into account the influence of absorption, grading of aggregates, etc., on the water content of the concrete.

In general, it is impracticable to determine in advance the exact quantity of water required for concrete mixes, largely due to two causes: (1) Inability to determine in advance the lowest relative consistency which may be used and still produce a workable concrete; (2) varying moisture content of aggregates.

The following table may be of interest in indicating the approximate quantities of water necessary for certain mixes. It is assumed that a well-graded aggregate up to 1½ inches in size will be used. Only under the most favorable conditions can the minimum values be used; in general, the maximum values need not be exceeded.

Mix		Approximate Mix as Usually Expressed			Water Required (Gallons per Sack of Cement)	
Cement	Volume of Aggregate After Mixing	Cement	Aggregate		Minimum	Maximum
			Fine	Coarse		
1	5	1	2	4	6	6½
1	4½	1	2	3	5¾	6¼
1	4	1	1½	3	5½	6
1	3	1	1¼	2½	5	5½

Without regard to the actual quantity of mixing water, the following rule is a safe one to follow:

> "Use the *smallest quantity* of mixing water that will produce a workable mix."

The importance of methods of proportioning, mixing, handling, placing or finishing concrete which will enable the builder to reduce the water content to a minimum is at once apparent.

Effect of Curing Condition on the Strength of Concrete.

The effect of curing condition on the compressive strength of concrete is shown in Fig. 5; an average curve is given in Fig. 9. All consistencies of concrete show great increases in strength under favorable curing conditions as compared with specimens which were allowed to dry out at once. The dryer mixes show a more rapid improvement due to storage in a damp place during the first few days than the wetter ones. Even 3 days in damp sand shows an increase in strength of the dryer concretes of about 35 per cent. as compared with the specimens stored in open air for the entire period. It should be borne in mind that in the most unfavorable case used in the experiments the concrete was in the steel form for 1 day with only the top exposed, consequently the conditions were more favorable than those frequently found in summer weather or in arid regions where the concrete is exposed to rapid evaporation of the mixing water from the moment it is placed.

The concrete stored for 4 months in damp sand and tested damp is 2½ to 3 times as strong as similar concrete which has been exposed to room atmosphere for the same period. Protecting the concrete from drying out for only 10 days (taking values from Figs. 5 and 9) gives an increase in strength of about 75 per cent. for the dryer mixes.

EFFECT OF CURING CONDITION ON THE WEAR OF CONCRETE.

The effect of curing condition on the wear of concrete is no less striking than the effect on the strength.

It will be seen in Fig. 7 that the blocks stored for the entire period of 4 months in damp sand showed more wear in most instances than those

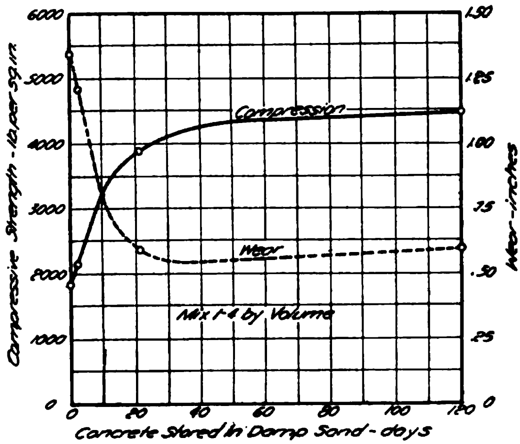


FIG. 9—EFFECT OF CURING CONDITION ON THE STRENGTH AND WEAR OF CONCRETE.

Average curves from Figs. 5 and 7. Each value for compression is the average of 24 tests (four each for six consistencies). Each value for wear is the average of 60 blocks (10 each for six consistencies). The upward trend of the wear curve results from the abnormal wear of the 4-month sand-stored blocks on account of being tested in damp condition.

which had been stored for 21 days in damp sand and the remainder of the time in air. This peculiar result is no doubt due to the fact that the concrete was tested in a damp condition, and does not indicate that the longer period in damp sand is injurious. The comparison would have been more nearly correct if the blocks had been allowed to dry out a few days before testing. These results do show that concrete in a wet or damp condition suffers more from wear than when dry. It is a matter of common experience that non-metallic materials, such as timber, terra cotta, concrete, stone, etc., which absorb water, show a lower strength

in a wet condition than when dry. Additional tests will be required to show the exact effect of moisture content on strength and wear of concrete, other factors being the same.

It is not necessary to speculate on the probable effect of moisture in the concrete in order to secure valuable information from these tests. The dryer mixes show an increase in wear from .50 inch for concrete stored in damp sand for 21 days, to 1.10 inches for concrete in air for entire period; the tests indicate that 10 days in damp storage would give a wear of about .65 inch. For the wetter mixes the wear after 21 days in damp sand is about .85 inch; for 10 days 1.15 inches; for air storage throughout probably 2 inches. In the wetter consistencies the tests were not carried to completion on account of disintegration of certain blocks, which caused the entire ring to collapse.

The photographs in Figs. 15 to 20 show side views of the blocks after test. The effect of both consistency and curing condition are clearly shown by the relative thickness of the blocks.

Recapitulation of Effect of Consistency and Curing Condition.

In view of the important influence of consistency and curing conditions of concrete shown by these tests, it seems doubtful if there is any phase of concrete work which will pay such high dividends as a little care to see that proper consistency is used and desirable curing conditions are provided. In many instances the quality of the concrete could be vastly improved at trifling expense, but nothing is done because those in charge do not appreciate the importance of care in these directions. The writer is convinced that practically all of the faults from concrete floors follow from these two causes. Excessive wear and dusting are certain to result in a floor in which the concrete is never allowed to have the water necessary for hydration of the cement. It is notable that dusting never occurs on a concrete road, for the reason that it gradually gets the water necessary for hydration from rain or snow. However, due to low wearing resistance at early periods, resulting from premature drying, it may be badly worn before rain comes.

An excess of mixing water is a serious fault in concrete. If, in addition to too much water the concrete is allowed to dry out at once it is almost certain to be a failure if subjected to wear and will give very low strength. For the two wettest consistencies and the two most unfavorable curing conditions, the compressive strength of the pebble concrete was 1300 pounds per square inch; for the two most favorable curing conditions and the three dryest consistencies the average compressive strength was 4850 pounds per square inch—an increase of 275 per cent. In the case of the wear tests the corresponding values are 1.70 inches and .50 inch; an increase of 240 per cent. The comparison in the wear test is not as unfavorable as it should have been, since the poorer blocks broke up before the test was completed.

Proper curing of concrete is second only in importance to the control of water content. The rule stated above with reference to water content may now be extended to the following:

> Use the *smallest quantity* of mixing water that will produce a workable concrete, then allow the concrete to have *as much water as possible* during the period of curing.

All concrete should be protected against premature drying for at least one week, and longer if practicable. This period should be extended to 10 days or two weeks in cool weather, or where the concrete is to be subjected to heavy traffic at an early age.

Covering with damp sand or earth, or wet burlap are excellent methods of curing. The practice of "ponding" is common in road construction. The writer wishes to offer a word of caution with reference to the use of wet sawdust for covering concrete floors. Sawdust may have most harmful results, on account of the organic acids present.

Compression tests of concrete made in other series show that the strength of concrete increases indefinitely, so long as it is not permitted to dry out.*

Relation Between Strength and Wear of Concrete.

The relation between strength and wear of concrete in this series is shown in Fig. 10. All tests have been platted. Each value is based on the average of four compression tests and 10 wear tests. This diagram shows that a definite relation exists between strength and wear at least for the conditions of these tests; that is, for concrete of different consistencies and curing conditions. Further tests will be necessary to show whether or not this relation is entirely general for other aggregates, etc.

Fig. 11 is the same curve platted to log. scale. The straight line in this diagram enables us to devise the equation:

$$S = \frac{2230}{W^{1.07}}$$

as showing the relation between the variables; where S = compressive strength in pounds per square inch and W = the depth of wear in inches.

A similar relation from another series of strength and wear tests made in this laboratory will be found in Figs. 14 and 15 of the paper on "Effect of Time of Mixing," referred to above.

Comparison of Pebble and Crushed Stone Aggregate.

Crushed limestone was used as coarse aggregate in one group of tests. In general the limestone concrete gave somewhat higher strength and lower wear than the gravel concrete using the same sand and the same water and cement. However, the tests do not cover a sufficient

*See "Effect of Age on the Strength of Concrete," by D. A. Abrams, Proc. American Society for Testing Materials, Part II, 1918.

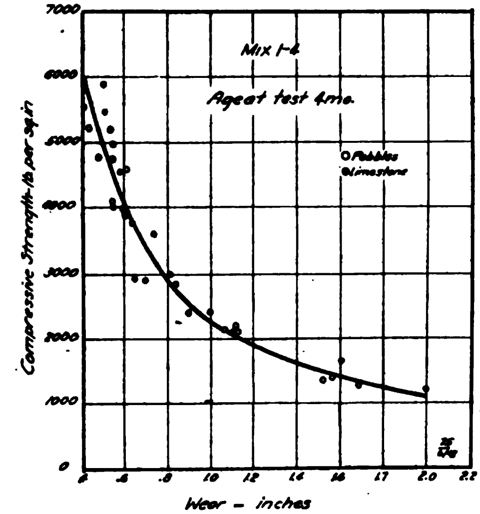


FIG. 10—RELATION BETWEEN THE COMPRESSIVE STRENGTH AND WEAR OF CONCRETE.

Compression tests of 6 x 12-inch cylinders, and wear tests of 8 x 8 x 5-inch blocks at age of 4 months. Each value is based on the averages of four compression tests and 10 wear tests. All consistencies and curing conditions are included.

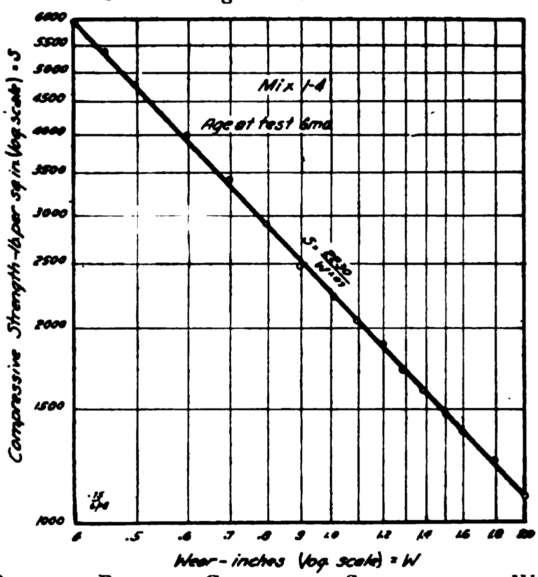


FIG. 11—RELATION BETWEEN COMPRESSIVE STRENGTH AND WEAR OF CONCRETE.

Same data as in Fig. 10, except curve platted on logarithmic scales. The points shown are taken from the curve in Fig. 10.

range to justify definite comparisons of the merits of the two types of aggregate. Both of the aggregates used in this series were of high grade and gave good results in the tests. Other tests now under way and planned for the future are expected to give definite information on the relative merits of different aggregates.

Method of Making Wear Tests.

The Talbot-Jones rattler has been found entirely successful as a method of studying the wear of concrete in the laboratory. The results

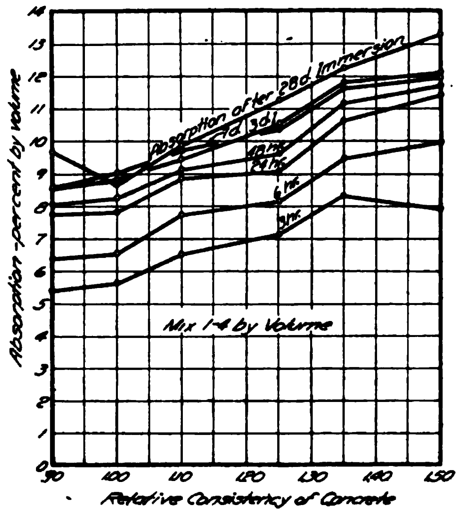


FIG. 12—EFFECT OF QUANTITY OF MIXING WATER ON THE ABSORPTION OF CONCRETE.

Absorption tests of 8 x 8 x 5-inch blocks. Pebble aggregate. Age 1 year. Absorption determined after immersion in water at room temperature. Each value is the average of eight blocks from four different curing conditions—one block from each set of pebble aggregates in Table 5. Absorption is given by volumes; absorption by weight is about 40 per cent. of these values.

of the tests thus far completed and the definite relations found between the wear and strength have given considerable confidence to this method of testing. The abrasive charge of 200 pounds of cast-iron balls, and the rate and number of revolutions used, gives a wearing action suited for a wide range in the properties of concrete. A very poor concrete may be entirely destroyed, a high-grade concrete will show a wear of ½ inch or less.

The test gives a combination of abrasion and impact that cannot be withstood by an inferior concrete. The severity of the impact may be

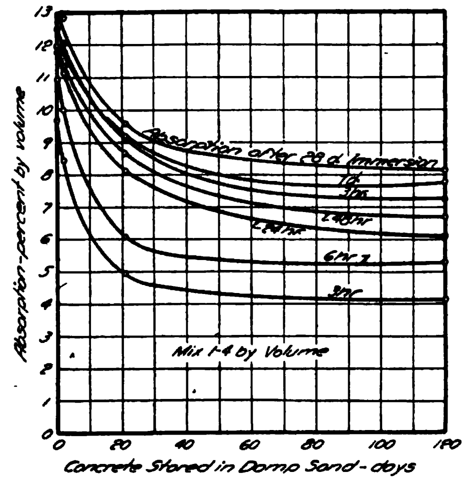


FIG. 13—EFFECT OF CURING CONDITIONS ON THE ABSORPTION OF CONCRETE. Absorption tests of 8 x 8 x 5-inch blocks. Absorption determined after immersion in water at room temperature. Each value is the average of 12 blocks from six different consistencies. Same data as in Fig. 12. Absorption is given by volumes; absorption by weight is about 40 per cent. of these values.

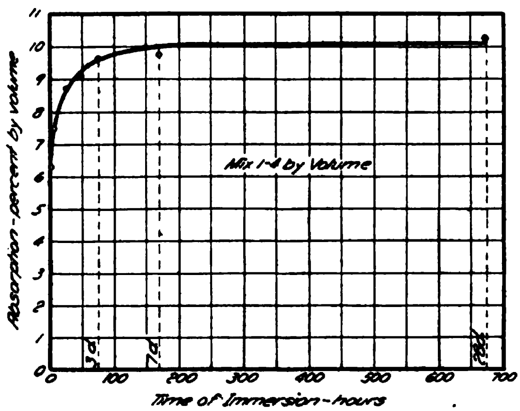


FIG. 14—EFFECT OF TIME OF IMMERSION ON THE ABSORPTION OF CONCRETE. Absorption tests of 8 x 8 x 5-inch blocks. Absorption determined after immersion in water at room temperature. Each value is the average of 48 tests from six consistencies and four curing conditions. Data from Table 5. Absorption is given by volumes; absorption by weight is about 40 per cent. of these values.

seen from the fact that the 1⅞-inch cast-iron balls are frequently broken during the test. While the test does not fully duplicate the action of traffic, it furnishes a valuable guide to the relative effects of different methods of treatment, materials, etc., for use in pavement construction.

This method of making wear tests of concrete is believed to have the following advantages as compared with other methods which have been used or proposed for this purpose:

(1) The concrete is subjected to a treatment which approximates that of service.

(2) The test piece is of usual form and of sufficient size that representative concrete can be obtained.

(3) The test pieces are convenient to make, store and handle, and require a relatively small quantity of concrete.

(4) The cost of tests is not excessive.

(5) The machine used is found in a number of testing laboratories.

(6) The wearing action takes place on the top or finished surface of the concrete. This makes it possible to study the effect of various surface treatments and finishes.

(7) Several tests may be made at the same time, thus enabling more representative results to be obtained.

(8) Tests may be made on sections of concrete cut from roads which have been in service.

(9) Other paving materials, such as brick, granite blocks, etc., may be tested in the same manner as the concrete.

Absorption Tests of Concrete.

Absorption was determined on two wear blocks from each set of 10, after immersion in water for periods of 3 hours to 28 days. It should be noted that absorption tests were made on blocks at the age of 1 year, which had been tested for wear at 4 months.

The results of absorption tests are given in Table 5, and in Figs. 13 and 14. In Fig. 13 all consistencies for a given curing condition have been averaged. It is interesting to note that the absorption is influenced by the curing condition of the concrete in the same way as the wear. (Compare Figs. 13 and 7.) The curing condition that gives high wear, gives high absorption, and vice-versa.

The effect of consistency and curing condition on absorption is shown by an average absorption of 5.77 per cent. for the most favorable conditions after 24-hour immersion and 12.6 per cent. for the most unfavorable conditions. The absorption is here given by volumes; the absorption by weight would be only about 40 per cent. of these values.

The effect of time of immersion on the absorption is shown in Fig. 14; all consistencies and curing conditions have been averaged for a given time of immersion.

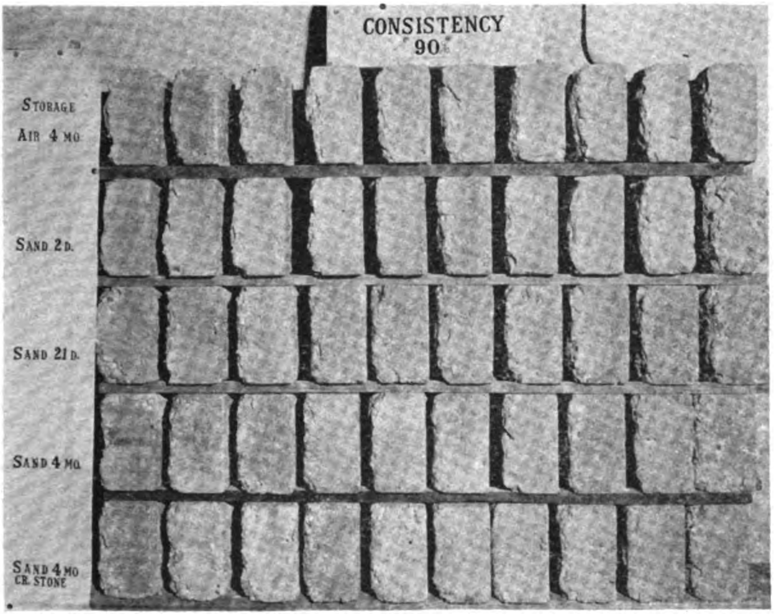


FIG. 15—SIDE VIEW OF WEAR BLOCKS AFTER TEST.
The effect of storage condition on wear is clearly shown.

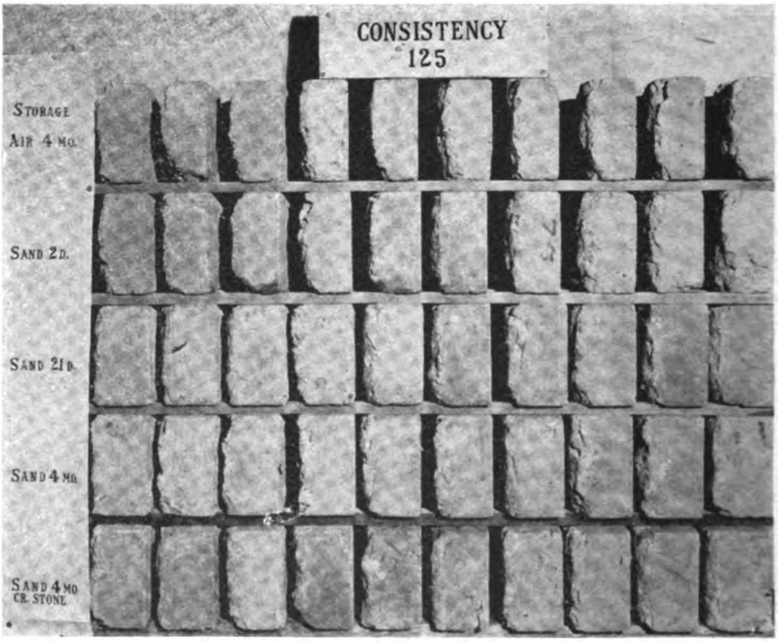


FIG. 18—SIDE VIEW OF WEAR BLOCKS AFTER TEST.
The effect of storage condition on wear is clearly shown.

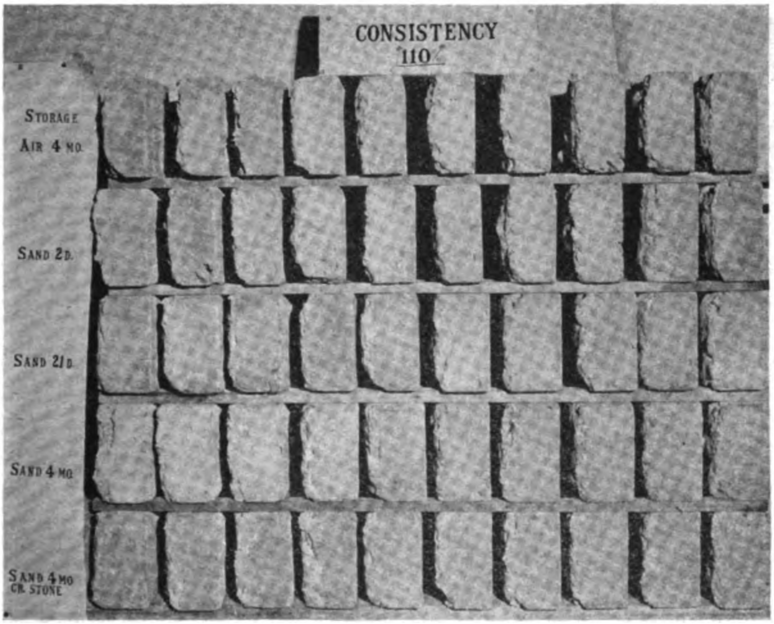


FIG. 17—SIDE VIEW OF WEAR BLOCKS AFTER TEST.
The effect of storage condition on wear is clearly shown.

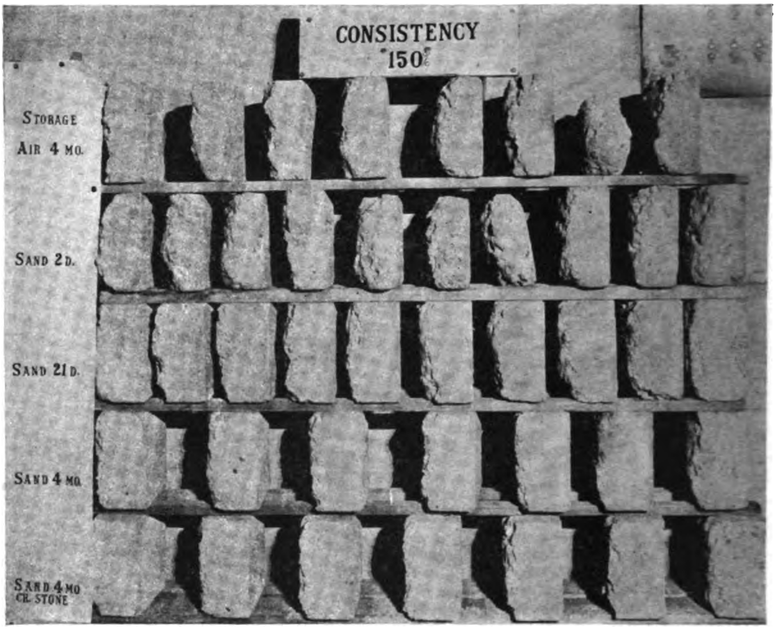


FIG. 20—SIDE VIEW OF WEAR BLOCKS AFTER TEST.

Some of the blocks which were stored for the entire four months in air were completely broken up before the end of the test run. The blocks missing from the two lower rows were lost before the photograph was taken.

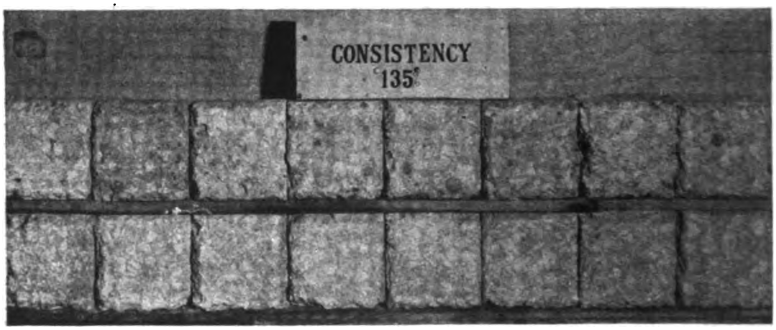


FIG. 21—FRONT VIEW OF WEAR BLOCKS AFTER TEST.

Top row, gravel as coarse aggregate.
Bottom row, crushed limestone as coarse aggregate.

Unit Weight of Concrete.

The unit weight of all test pieces was determined immediately before test at the age of 4 months. The values are given in Table 6. Each value is the average from four cylinders and 10 wear blocks. The weight of the concrete is little affected by the consistency, but is greatly influenced by the curing condition. The weights of the specimens stored for 4 months in damp sand cannot be compared directly with the others, since they contained free moisture; that is, water in the uncombined state. A comparison of the average weights of all consistencies for the other curing conditions shows that the concrete stored 3 days in damp sand took up .33 pound more water and that stored for 21 days in damp sand 2.16 pounds more water per cubic foot than that stored in air throughout the 4 months. Since all test pieces were in the same room-dry condition when the weights were determined, it seems that these values may be taken as approximate measures of the additional quantities of water which have entered into chemical combination with the cement, due to storage in a damp place for these periods.

Table 1—Tests of Cement.

The cement consisted of a mixture of equal parts of four brands purchased on the Chicago market (Lot No. 3705).

All tests made in accordance with standard methods of the American Society for Testing Materials.

Miscellaneous Tests.

Fineness Residue on 200 Sieve	Normal Consistency Per Cent by Weight	Time of Setting				Soundness Test (over Boiling Water)
		Vicat Needle		Gillmore Needle		
		Initial	Final	Initial	Final	
		h. m.	h. m.	h. m.	h. m.	
20.4	23.0	4.25	8 05	5.10	8.45	O.K.

Mortar Strength Tests.

1-3 standard sand mortar.

Mixing Water Percent	Briquets Tensile Strength — lb. per sq. in.						2 by 4-in. Cylinders Compressive Strength — lb. per sq. in.					
	7 Da.	28 Da.	3 Mo.	6 Mo.	1 Yr.	2 Yr.	7 Da.	28 Da.	3 Mo.	6 Mo.	1 Yr.	2 Yr.
10.3	266	367	464	431	415	357	2060	3800	4240	5130	5060	4600

TABLE 2—SIEVE ANALYSIS OF AGGREGATES.

Sieves manufactured by the W. S. Tyler Company, Cleveland, Ohio.

Sieve Number or Size	Size of Clear Opening inches	Per Cent. by Weight Coarser than Each Sieve				
		Sand	Pebbles	Crushed Limestone	Sand and Pebbles	Sand and Limestone
100	.0058	98	100	100	99	99
48	.0116	90	100	100	96	96
28	.028	60	100	100	84	84
14	.046	42	100	100	77	77
8	.093	22	100	100	69	69
4	.185	0	100	100	60	60
3/8	.37	....	84	84	50	50
3/4	.75	....	50	50	30	30
1 1/4	1.25	....	0	0	0	0

TABLE 3—MISCELLANEOUS TESTS OF AGGREGATES.

Test	Sand	Pebbles	Crushed Lime-stone	Sand and Pebbles	Sand and Limestone
Unit Weight of Dry Aggregate lb. per cu. ft.	115.5	112.5	99.5	131.0	123.0
Absorption of Aggregate †					
Per cent. by volume................	2.3	2.2	1.6	....	....
Per cent. by weight................	1.3	1.3	1.0	....	....
Abrasion Test ‡					
Loss in weight—per cent.					
Standard method..................	....	2.3	5.2	....	....
Rea's method....................	....	8.8	12.3	....	....

†After immersion in water at room temperature for 3 hrs.

‡Abrasion tests were made in the Deval abrasion testing machine. In the Standard method a sample of 50 pieces weighing 5000 g. was placed in the test chamber and run for 10,000 revolutions. Rea's method was first used by A. S. Rea, of the Ohio State Highway Department, Columbus. It consists in using a 5000-g. sample, made up of 2500 g. of aggregate ½ to ¾ in. in size and 2500 g. of aggregate ¾ to 1¼ in. In addition to the aggregate six 1⅞ in. cast-iron balls were placed in the test chamber as an abrasive charge. The entire sample was run for 10,000 revolutions. It will be seen that Rea's method is much more severe than the Standard method.

Table 4—Wear and Compression Tests of Concrete.

Hand-mixed concrete. Mixed 1-4 by volume. Age at test, 4 months.
Aggregate graded 0-1¼ in.
The same sand used in all tests.
Coarse aggregate consisted of pebbles or crushed limestone of the same grading.
The specimens were stored for the period shown in damp sand, the remainder of the time in the air of the Laboratory.
Wear tests made in Talbot-Jones rattler—total of 1800 revolutions.
Wear tests are average of five 8 by 8 by 5-in. blocks.
Compression tests are average of two 6 by 12-in. cylinders.
The second set of tests in each group was made 2 to 4 weeks after the first.

Coarse Aggregate	Mixing Water		Depth of Wear—Inches 8 by 8 by 5-Inch Blocks				Compressive Strength—Lbs. Per Sq. In. 6 by 12-Inch Cylinders			
	Relative Consistency	Water Ratio	Damp Sand Storage	21 Days in Damp Sand	3 Days in Damp Sand	Air Storage	Damp Sand Storage	21 Days in Damp Sand	3 Days in Damp Sand	Air Storage
Pebbles	.90	.66	.53	.34	.82	1.29	4970	5310	2890	2110
			.54	.51	.84	.91	4990	5150	2720	2260
			.54	.43	.83	1.10	4980	5230	2810	2190
Crushed Limestone	.90	.66	.48	......	......	......	5970	......	......	......
			.52	......	......	......	5700	......	......	......
			.50				5890			
Pebbles	1.00	.73	.54	.52	.83	1.01	5530	4550	3040	2290
			.52	.41	.78	1.10	4760	4960	2960	2020
			.53	.47	.81	1.06	5200	4760	3000	2160
Crushed Limestone	1.00	.73	.34	......	......	......	5800	......	......	......
			.46	......	......	......	5280	......	......	......
			.40				5540			
Pebbles	1.10	.81	.52	.51	1.00	1.23	4470	3940	2350	2240
			.56	.54	.98	1.02	5020	4220	2410	2050
			.54	.53	.99	1.12	4750	4080	2380	2150
Crushed Limestone	1.10	.81	.48	......	......	......	5390	......	......	......
			.52	......	......	......	5540	......	......	......
			.50				5470			
Pebbles	1.25	.91	.57	.51	.96	1.56	4700	4350	2360	1640
			.63	.56	1.25	1.64	4490	3640	1900	1710
			.60	.54	1.10	1.60	4600	4000	2130	1680
Crushed Limestone	1.25	.91	.58	......	......	......	4320	......	......	......
			.56	......	......	......	4850	......	......	......
			.57				4590			
Pebbles	1.35	.99	.59	.69	1.49	2.40	3860	2570	1400	1420
			.66	.69	1.61	1.51*	3650	3190	1310	1250
			.63	.69	1.55	1.51 1.51*	3760	2880	1360	1340
Crushed Limestone	1.35	.99	.59	......	......	......	3910	......	......	......
			.61	......	......	......	3820	......	......	......
			.60				3870			
Pebbles	1.50	1.09	.74	.85	2.34	1.68	3740	2300	1330	1280
			.73	.92	2.00*	....†	3530	2440	1090	1240
			.73	.89	....† 2.00*	1.68	3640	2370	1210	1260
Crushed Limestone	1.50	1.09	.60	......	......	......	2640	......	......	......
			.68	......	......	......	3190	......	......	......
			.64				2920			

*Omitting one badly damaged block.
†One block disintegrated, allowing entire charge to fall out after about 1100 revolutions.

Table 5—Absorption Tests of Concrete.

Hand-mixed concrete.
Mix 1-4 by volume.
Aggregate graded 0-1¼ in.

The same sand used in all tests—torpedo sand from Elgin, Ill.

Coarse aggregate consisted of pebbles or crushed limestone of same grading.

Age at test 1 year. The tests were made on 8 by 8 by 5-in. concrete blocks which had previously been used in wear tests at the age of 4 months. Immediately after molding the blocks were stored for the period shown in damp sand, the remainder of the time in the air in the Laboratory.

During the absorption test the blocks were immersed in water at room temperature.

Each value is the average of 2 blocks made on different days.

Coarse Aggregate	Mixing Water		Absorption—Per Cent. by Volume											
	Relative Consistency	Water Ratio	Damp Sand Storage	21 Days in Damp Sand	3 Days in Damp Sand	Air Storage	Damp Sand Storage	21 Days in Damp Sand	3 Days in Damp Sand	Air Storage	Damp Sand Storage	21 Days in Damp Sand	3 Days in Damp Sand	Air Storage
			3 Hours				6 Hours				24 Hours			
Pebbles........	.90	.66	3.17	3.93	6.41	8.09	3.81	4.49	7.70	9.53	4.99	6.26	8.84	11.00
Cr. Limestone..	.90	.66	4.66	.....	.....	.....	5.15	.....	.....	.....	6.52	.....	.....	.....
Pebbles........	1.00	.73	4.47	4.00	6.71	7.32	5.05	4.50	7.96	8.74	6.11	6.05	9.59	9.61
Cr. Limestone..	1.00	.73	2.53	.....	.....	.....	3.47	.....	.....	.....	4.71	.....	.....	.....
Pebbles........	1.10	.81	2.58	5.07	8.18	10.30	4.77	6.06	9.58	10.66	5.11	8.00	10.60	11.80
Cr. Limestone..	1.10	.81	2.89	.....	.....	.....	4.16	.....	.....	.....	4.75	.....	.....	.....
Pebbles........	1.25	.91	5.56	4.23	8.52	10.20	5.48	5.82	9.91	11.40	5.99	7.67	10.60	12.10
Cr. Limestone..	1.25	.91	4.30	.....	.....	.....	5.27	.....	.....	.....	6.02	.....	.....	.....
Pebbles........	1.35	.99	4.58	6.25	11.90	10.70	5.97	7.63	12.81	11.61	7.21	9.86	13.60	11.90
Cr. Limestone..	1.35	.99	4.72	.....	.....	.....	6.23	.....	.....	.....	7.40	.....	.....	.....
Pebbles........	1.50	1.09	4.58	6.36	9.11	11.60	6.56	7.85	11.92	13.65	7.16	10.90	13.50	14 30
Cr. Limestone..	1.50	1.09	5.07	.....	.....	.....	5.52	.....	.....	.....	8.44	.....	.....	.....
			48 Hours				3 Days				7 Days			
Pebbles........	.90	.66	5.08	6.76	9.06	11.36	6.08	7.06	9.35	11.75	6.46	7.31	9.44	11.16
Cr. Limestone..	.90	.66	6.74	.....	.....	.....	6.03	.....	.....	.....	6.98	.....	.....	.....
Pebbles........	1.00	.73	6.20	7.06	10.00	9.69	6.54	7.72	10.58	10.53	7.24	7.55	10.34	10.90
Cr. Limestone..	1.00	.73	4.85	.....	.....	.....	5.56	.....	.....	.....	5.76	.....	.....	.....
Pebbles........	1.10	.81	5.49	9.26	9.98	11.85	6.88	8.70	10.74	12.35	6.76	9.72	11.45	10.95
Cr. Limestone..	1.10	.81	5.26	.....	.....	.....	6.20	.....	.....	.....	6.90	.....	.....	.....
Pebbles........	1.25	.91	7.30	7.94	11.20	12.00	7.65	9.22	13.05	12.30	7.42	9.14	13.50	11.50
Cr. Limestone..	1.25	.91	6.54	.....	.....	.....	7.08	.....	.....	.....	8.06	.....	.....	.....
Pebbles........	1.35	.99	8.05	10.14	14.20	12.30	8.94	10.42	14.75	13.22	8.98	10.21	14.40	12.97
Cr. Limestone..	1.35	.99	7.91	.....	.....	.....	8.35	.....	.....	.....	8.85	.....	.....	.....
Pebbles........	1.50	1.09	8.02	10.95	13.50	14.45	8.49	11.45	13.65	14.86	9.92	10.81	12.92	14 32
Cr. Limestone..	1.50	1.09	8.82	.....	.....	.....	9.16	.....	.....	.....	9.10	.....	.....	..
			28 Days											
Pebbles........	.90	.66	9.07	7.82	9.63	12.22								
Cr. Limestone..	.90	.66	7.54	.....	.....	.....								
Pebbles........	1.00	.73	5.68	7.84	10.92	10.25								
Cr. Limestone..	1.00	.73	5.92	.....	.....	.....								
Pebbles........	1.10	.81	7.00	9.43	11.68	11.27								
Cr. Limestone..	1.10	.81	5.64	.....	.....	.....								
Pebbles........	1.25	.91	7.88	9.84	14.25	13.18								
Cr. Limestone..	1.25	.91	8.30	...	.....	.....								
Pebbles........	1.35	.99	9.13	10.74	15.08	14.19								
Cr. Limestone..	1.35	.99	9.43	.....	.....	.....								
Pebbles........	1.50	1.09	10.15	11.72	15.40	16.50								
Cr. Limestone..	1.50	1.09	9.23	.....	.....	.....								

TABLE 6—UNIT WEIGHT OF CONCRETE.

Hand-mixed concrete.
Mix 1-4 by volume.
Weighed immediately before test at age of 4 months.
Aggregate graded 0-1¼-in.
The same sand used in all tests.
Coarse aggregate consisted of pebbles or crushed limestone of same grading.
The tests were made on 8 by 8 by 5-in. blocks and 6 by 12-in. cylinders.
Test pieces were stored for the period shown in damp sand, the remainder of the time in the air of the laboratory.
Each value is the average of 4 cylinders and 10 wear blocks.

Coarse Aggregate	Mixing Water		Weight—lb. per cu. ft.			
	Relative Consistency	Water Ratio	Damp Sand Storage	21 Da. in Damp Sand	3 Da. in Damp Sand	Air Storage
Pebbles	.90	.66	155.8	148.5	147.0	147.0
Crushed Limestone	.90	.66	152.5	....	....	....
Pebbles	1.00	.73	157.0	153.0	152.0	151.0
Crushed Limestone	1.00	.73	152.0	....	....	....
Pebbles	1.10	.81	156.9	152.0	150.5	149.8
Crushed Limestone	1.10	.81	156.0	....	....	....
Pebbles	1.25	.91	155.9	152.0	148.5	148.0
Crushed Limestone	1.25	.91	156.2	....	....	....
Pebbles	1.35	.99	156.9	152.0	149.8	150.2
Crushed Limestone	1.35	.99	155.6	....	....	....
Pebbles	1.59	1.09	154.8	149.5	148.2	148.0
Crushed Limestone	1.50	1.09	156.0	....	....	....

Appendix E.

REPORT ON SUBJECT (7).

W. M. KINNEY, Chairman, Sub-Committee.

(I)

Concrete which is allowed to dry out during the early stages of hardening has less strength and less resistence to wear than concrete provided with plenty of moisture during this period. It is just as harmful to fail to provide moisture to the hardening concrete as it is to use an excess of water in mixing.

(II)

Moisture can best be provided to hardening concrete by covering the concrete with earth, sand, straw or other moisture-retaining material and sprinkling this covering at least night and morning for from one to two weeks after the concrete has been placed. If the days are real hot, additional sprinklings during the day will be required and the covering should be thicker so that drying out will take place less rapidly. This method is particularly applicable to large areas. For other types of work the forms can be left on as long as possible, covering the surface of the concrete with tarpaulins to prevent rapid drying out at the surface. These tarpaulins can be sprinkled in warm weather.

In the case of reinforced concrete buildings, the buildings can be enclosed with canvas or other material and each floor sprinkled. Even without enclosing the structure with canvas, sprinkling will be beneficial.

Many schemes will suggest themselves to contractors, depending upon the character of work.

In a number of localities where earth covering was not available, concrete roads have been cured by the ponding method. Small dikes are built along the edge of the road and across the road every 30 or 40 feet. The space between these dikes is then flooded with water. This method would be applicable for station platforms, driveways, etc.

(III)

Concrete which has hardened with insufficient moisture can be improved somewhat by sprinkling even after it is several weeks old. However, such concrete will never reach the strength which it might have obtained had proper precaution been given in the early stages of hardening.

The most serious result from such failure to provide moisture occurs with sidewalks, floors, station platforms, etc. Several chemicals are recommended for treating such floors and seem to have some merit, although the treatment is expensive and the applications must be made at intervals. Providing moisture during the early stages of hardening gives satisfactory results and much better insurance against poor results.

REPORT OF COMMITTEE XII—ON RULES AND ORGANIZATION.

W. H. Finley, *Chairman;*
F. D. Anthony, *Vice-Chairman;*
O. F. Barnes,
A. J. Himes,
E. H. Barnhart,
F. D. Lakin,
W. C. Barrett,
B. M. McDonald,
H. L. Browne,
Jos. Mullen,
J. B. Carothers,
E. T. Reisler,
S. E. Coombs,
W. H. Rupp,
C. Dougherty,
P. T. Simons,
H. H. Edgerton,
R. E. Warden,
B. Herman,
Committee.

To the American Railway Engineering Association:

Your Committee was requested by the Board of Direction to report on the following subjects:

1. Make critical examination of the subject-matter in the Manual, and submit definite recommendations for changes.
2. Prepare a "Manual of Instructions for the Guidance of Engineering Field Parties."
3. Continue the study of the Science of Organization.
4. Prepare a "Manual of Rules for the Guidance of Employees of the Maintenance of Way Department."
5. Prepare rules for the construction, maintenance and operation of buildings and protective apparatus for the reduction of fire risk.
6. Prepare rules for the inspection of bridges and culverts.

The various subjects were assigned to Sub-Committees for study and report.

The Committee has held one general meeting, in addition to the meetings of the several Sub-Committees.

On Subject (1), Revision of Manual, your Committee reports that it has no changes to recommend at this time.

Subject (2), progress is reported.

Subject (3), Science of Organization, the conditions prevailing during the past year have made it impracticable to make a final report. As a matter of interest, your Committee submits in Appendix A a reprint from Engineering News-Record of December 12, 1918, containing "John D. Rockefeller Jr.'s Industrial Creed."

A large amount of work has been done on Subject (4), "Manual of Rules for the Guidance of Employees of the Maintenance of Way Department," but the data is not in shape to be presented at this meeting, and hence the Committee asks for further time in which to complete this topic.

Progress is also reported on Subjects (5) and (6).

Your Committee recommends that the same subjects be reassigned for the coming year.

Respectfully submitted,

Committee on Rules and Organization.

Appendix A.

SCIENCE OF ORGANIZATION.

JOHN D. ROCKEFELLER JR.'S INDUSTRIAL CREED.*

Principles He Laid Down at the Reconstruction Congress at Atlantic City.

1. I believe that labor and capital are partners, not enemies; that their interests are common interests, not opposed, and that neither can attain the fullest measure of prosperity at the expense of the other, but only in association with the other.

2. I believe that the community is an essential party to industry and that it should have adequate representation with the other parties.

3. I believe that the purpose of industry is quite as much to advance social well-being as material well-being and that in the pursuit of that purpose the interests of the community should be carefully considered, the well-being of the employees as respects living and working conditions should be fully guarded, management should be adequately recognized and capital should be justly compensated, and that failures in any of these particulars means loss to all four.

4. I believe that every man is entitled to an opportunity to earn a living, to fair wages, to reasonable hours of work and proper working conditions, to a decent home, to the opportunity to play, to learn, to worship and to love, as well as to toil, and that the responsibility rests as heavily upon industry as upon government or society, to see that these conditions and opportunities prevail.

5. I believe that industry, efficiency and initiative, wherever found, should be encouraged and adequately rewarded, and that indolence, indifference and restriction of production should be discountenanced.

6. I believe that the provision of adequate means of uncovering grievances and promptly adjusting them is of fundamental importance to the successful conduct of industry.

7. I believe that the most potent measure of bringing about industrial harmony and prosperity is adequate representation of the parties in interest; that existing forms of representation should be carefully studied and availed of in so far as they may be found to have merit and are adaptable to the peculiar conditions in the various industries.

8. I believe that the most effective structure of representation is that which is built from the bottom up, which includes all employees, and, starting with the election of representatives in each industrial plant, the formation of joint works' committees, of joint district councils, and annual joint conferences of all the parties in interest in a single industrial corporation, can be extended to include all plants in the same industry, all industries in a community, in a nation, and in the various nations.

*Reprinted by permission from Engineering News-Record, December 12, 1918.

9. I believe that the application of right principles never fails to effect right relations; that "the letter killeth and the spirit maketh alive;" that forms are wholly secondary, while attitude and spirit are all-important, and that only as the parties in industry are animated by the spirit of fair play, justice to all and brotherhood, will any plans which they may mutually work out succeed.

10. I believe that that man renders the greatest social service who so co-operates in the organization of industry as to afford to the largest number of men the greatest opportunity for self-development and the enjoyment by every man of those benefits which his own work adds to the wealth of civilization.

REPORT OF COMMITTEE XVI—ON ECONOMICS OF RAILWAY LOCATION.

R. N. BEGIEN, *Chairman (Director)*; C. P. HOWARD, *Vice-Chairman*;

F. H. ALFRED,	E. H. MCHENRY,
A. S. BALDWIN *(Past-President)*,	G. A. MOUNTAIN,
WILLARD BEAHAN,	EDWARD C. SCHMIDT,
E. J. BEUGLER,	A. K. SHURTLEFF *(Asst. Secretary)*,
RALPH BUDD,	C. H. SPLITSTONE,
W. J. CUNNINGHAM,	M. F. STEINBERGER,
C. F. W. FELT,	A. F. STEWART,
R. D. GARNER,	L. L. TALLYN,
A. S. GOING,	ROBT. TRIMBLE *(Past-President)*,
A. J. HIMES,	W. F. TYE,
H. C. IVES,	W. L. WEBB,
W. A. JAMES,	H. C. WILLIAMS,
J. A. LAHMER,	M. A. ZOOK,
FRED LAVIS,	*Committee.*

To the American Railway Engineering Association:

The following subjects were assigned:

1. Make critical examination of the subject-matter in the Manual, and submit definite recommendations for changes, taking into special consideration a revision of the conclusions in Vol. 16, pages 104 to 109.
2. Report on the resistance of trains running between 35 and 75 miles per hour.
3. (a) Report on the effect of curvature on cost of maintenance of way.
   (b) Report on the effect of curvature on maintenance of equipment.
4. Report on the effect of train resistance on the amount of fuel consumed.
5. Report on the entire question of economics of location as affected by the introduction of electric locomotives.

Sub-Committees were appointed to consider each of the subjects assigned, but four of the Chairmen of Sub-Committees asked to be relieved. Only one Chairman responded that he would undertake the work, and only one Committee did any work. The report of that Committee is herewith appended.

No criticism is offered on account of the failure to devote time to the work of this Committee during the war period. Some of the members were in military service, and practically all were deep in war work throughout the entire period of time.

Respectfully submitted,

COMMITTEE ON ECONOMICS OF RAILWAY LOCATION.

Appendix A.

EFFECT OF CURVATURE ON COST OF MAINTENANCE OF WAY AND EQUIPMENT.

C. P. HOWARD, Chairman, Sub-Committee.

The subjects assigned this Sub-Committee were:

(a) Effect of curvature on cost of maintenance of way;

(b) Effect of curvature on cost of maintenance of equipment.

A meeting of members of the Sub-Committee was held at Chicago, July 23, at which were present Messrs. L. L. Tallyn, Robert Trimble and C. P. Howard.

It was decided not to circularize all the railroads, the times not being propitious, but to address officials of a few lines asking for any data they might have as to the various elements of curve expense.

(The Circular of Inquiry was published in Bulletin 210, October, 1918, pp. 79, 80.)

Several replies were received, but the only information obtained was from the Pennsylvania Lines, and is considered of such importance that it is made the basis of this report. This data is as follows:

"An investigation was made by the Pennsylvania Lines West of Pittsburgh during the years 1908 and 1911, inclusive, some of the results of which appear to throw some light upon the effect of curvature on the cost of maintenance.

"The investigation referred to was to determine as to whether or not lubrication of rails on curves would reduce rail wear and thereby result in corresponding economies. In order to present comparative estimates showing this it was necessary, so far as possible, to determine the relation between the wear of rails on straight lines as compared with wear on curved line of varying degrees.

"Table A below gives data concerning rail renewals on straight and curved track on 164 miles of the Eastern Division of the P., Ft. W. & C. Railway from Rochester to Crestline, for a period of thirty-one years.

TABLE A.

	Average Length of Track	Length of Track Renewed in 31 Years	Number of Renewals in 31 Years	Average Life, Years	Ratio of Renewals Tangent Being Equal to 1
Tangent	1,037,633	2,988,561	2.88	10.76	1.00
Curve 0° to 10'	117,107	332,539	2.84	10.90	.99
Curve 1° to 2°	157,323	510,289	3.24	9.57	1.12
Curve 2° to 3°	79,847	267,823	3.35	9.25	1.16
Curve 3° to 4°	46,384	186,291	4.01	7.73	1.39
Curve 4° to 5°	34,819	153,764	4.42	7.04	1.53
Curve 5° to 6°	4,580	24,146	5.27	5.90	1.82

"On account of the physical characteristics of the portion of the road investigated there is no data covering curves over six degrees. The information contained in this table has been plotted graphically, and an effort has been made to plot a curve showing a fair average of the results obtained. (See Diagram.)

"Table B below gives the length in miles and percentages of straight and curved track on the Pennsylvania Lines West for all main tracks.

TABLE B.

	ROAD		ALL TRACKS	
	Miles	Per Cent.	Miles	Per Cent.
Straight	2212	80.9	3365	78.4
Curves 2 degrees and under	269	9.8	487	11.3
Curves over 2 degrees, under 4 degrees	168	6.1	286	6.6
Curves 4 degrees and over	83	3.0	151	3.5
Total—Curved	520	19.1	924	21.5
Total—Straight and Curved	2733	100.0	4289	100.0

"The ratio of wear for different degrees of curve has been combined with the lengths and percentages of straight and curved track and these results are shown in Table C below.

TABLE C.

Number of Miles		Ratio of Wear	Equivalent Miles of Straight Track
3365	Straight	1.00	3365
487	Curves 2 degrees and under	1.10	536
286	Curves 2 and under 4 degrees	1.30	372
151	Curve over 4 degrees	1.60	242
4289		1.076	4515

"This table indicates that the increased wear of rail due to curvature is about 7.6 per cent.

"The result as developed in Table C would have been more accurate if the length of curves had been given by increments of one degree instead of 2 degrees. Inasmuch as it would require considerable work to make this separation it was deemed unnecessary in the present case to go to this trouble.

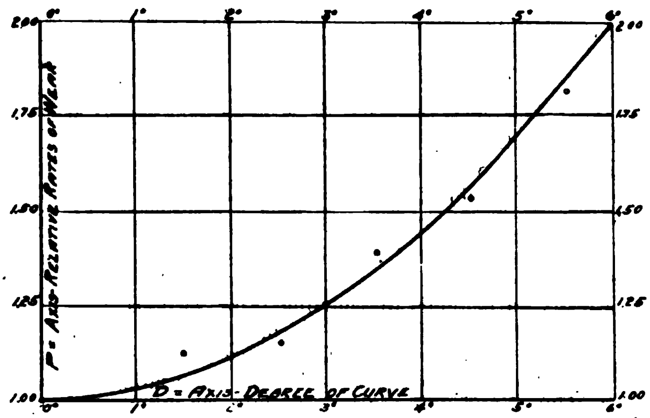
"It would seem * * * a fair assumption that other maintenance of way expenses due to curvature would increase in about the same proportion as that for renewals of rails and that the expenses will vary on each line or part of line according to the amount and degree of curve."

It will be noted that the average increase in rail wear on curves as compared with tangents is about 100 per cent. for a six-degree curve; 25 per cent. for a three-degree, etc., or approximately as the square of the degree of curve. The importance of this information is evident when it is remembered that heretofore it has been customary to estimate curve expense directly with the central angle, or with the degree of curve when a given length is considered.

It has been suggested that it would be a fair assumption that other maintenance of way expenses due to curvature would increase in about the same proportion as that for renewals of rails. Your Committee feels, however, that though such a tendency may be approximately true

for some expenses of maintenance, it would be more conservative to submit at this time such actual data as has been secured, hoping that further investigations and additional information will enable them to formulate with greater confidence and point out such parallels where they exist.

The Committee has no conclusions to submit at this time.



P = Percentage of Increase
D = Degree of Curve
Formula

$$P = \frac{25D^2}{9}$$

DIAGRAM SHOWING RELATION
BETWEEN WEAR OF RAIL ON STRAIGHT LINE
AS COMPARED WITH THAT ON CURVES
BASED ON RECORDS
OF
PENNSYLVANIA LINES WEST OF PITTSBURGH
November 1918

REPORT OF COMMITTEE XXII—ON ECONOMICS OF RAILWAY LABOR.

E. R. LEWIS, *Chairman;*
W. J. BACKES,
R. A. BALDWIN,
J. Q. BARLOW,
A. F. BLAESS,
W. M. CAMP,
W. R. DAWSON,
R. C. FALCONER,
R. H. FORD,
W. R. HILLARY,
C. B. HOYT,
C. H. STEIN, *Vice-Chairman;*
W. H. HOYT,
E. D. JACKSON,
C. M. JAMES,
C. E. JOHNSTON,
A. C. MACKENZIE,
*JOHN C. NELSON,
C. A. PAQUETTE,
J. W. PFAU,
H. R. SAFFORD,
†LIEUT.-COL. H. J. SLIFER,
Committee.

To the American Railway Engineering Association:

Your Committee on Economics of Railway Labor submits its report to the Twentieth Annual Convention.

The following subjects were assigned your Committee by the Board of Direction:

1. Report on plans and methods for organizing to obtain labor for railways.
2. Report on methods of equating track sections.
3. Report on typical plans for boarding cars and boarding houses for railway laborers, conferring with Committee on Buildings.
4. Study the matter of establishing proper relations between unit of track expenditure and unit per mile of line for different classes of road for the purpose of determining a normal maintenance expense and to obtain as far as possible uniform conditions involving: (a) Separation of expenses as between Road, Signal and Bridge and Building Departments; (b) The determination of the ratio of labor cost to total cost.
5. Report on labor-saving devices.

COMMITTEE MEETINGS.

Meetings of the whole Committee were held in Chicago on June 11, September 10 and November 8, in addition to the meetings held by the various Sub-Committees.

(1) REPORT ON PLANS AND METHODS FOR ORGANIZING TO OBTAIN LABOR FOR RAILWAYS.

Your Committee has considered this subject and finds that under present circumstances it seems advisable to continue investigation before presenting any set plan of organization for your consideration. Your Committee reports progress on this subject.

*Died, October 6, 1918. †Died in France, February 3, 1919.

(2) REPORT ON METHODS OF EQUATING TRACK SECTIONS.

Your Committee presents in Appendix "A" its report on the methods now in use.

(3) REPORT ON TYPICAL PLANS FOR BOARDING CARS AND BOARDING HOUSES FOR RAILWAY LABORERS, CONFERRING WITH COMMITTEE ON BUILDINGS.

Your Committee presents in Appendix "B" tentative outline plans with explanations, with a view to criticism before taking up detail drawings.

(4) STUDY THE MATTER OF ESTABLISHING PROPER RELATIONS BETWEEN UNIT OF TRACK EXPENDITURE AND UNIT PER MILE OF LINE, FOR DIFFERENT CLASSES OF ROAD FOR THE PURPOSE OF DETERMINING A NORMAL MAINTENANCE EXPENSE AND TO OBTAIN, AS FAR AS POSSIBLE, UNIFORM CONDITIONS INVOLVING (a) SEPARATION OF EXPENSES AS BETWEEN ROAD, SIGNAL AND BRIDGE AND BUILDING DEPARTMENTS; (b) THE DETERMINATION OF THE RATIO OF THE LABOR COST TO TOTAL COST.

Your Committee presents in Appendix "C" a study of this subject as a progress report.

(5) REPORT ON LABOR-SAVING DEVICES.

Your Committee presents in Appendix "D" a list of 60 labor-saving devices with short descriptions of these machines and their purposes.

CONCLUSIONS.

Your Committee recommends:

Subject (2). That the report on methods of equating track sections be accepted as information and printed in the Proceedings.

Subject (3). That the report on typical plans for boarding cars and boarding houses for railway laborers be received as a progress report. (To be considered further at the next convention.)

Subject 4. That the study of relations of units of track expenditure to units of mile of line with view of determining a normal maintenance expense and to obtain, as far as possible, uniform conditions involving (a) Separation of expenses as between Road, Signal and Bridge

and Building Departments; (b) The determination of the ratio of labor cost to total cost, be received as a progress report.

RECOMMENDATIONS FOR FUTURE WORK.

Your Committee recommends for next year's work: continuation of subjects (1), (3) and (4).

Respectfully submitted,

COMMITTEE ON ECONOMICS OF RAILWAY LABOR.

Appendix A.

(2) EQUATING TRACK SECTIONS.

E. T. HOWSON, *Chairman;*
H. R. SAFFORD,
R. H. FORD,
C. H. STEIN,
R. A. BALDWIN,
C. M. JAMES,
Sub-Committee.

Labor constitutes the largest single item of maintenance of way expense; in fact, it is larger than all other expenditures combined, aggregating approximately 56 per cent. of all charges of this department. From its nature it is the expenditure in which there is the greatest opportunity for the display of economy and likewise the greatest danger of waste and inefficiency. It would, therefore, naturally be expected that the distribution of this expenditure, aggregating over one-half million dollars a day, would be surrounded with elaborate safeguards to insure the greatest return. Yet investigation shows that the reverse is true. As a result, the allotments are commonly made on an arbitrary basis of so many men per section, with only very general consideration of the relative amounts of work to be done.

In the discussion of labor distribution the gang is the unit in the maintenance of way organization. As the larger part of the employees in this department are engaged in track maintenance and are employed in section gangs, the Committee has confined its discussion to this class of work, although the general principles apply equally to other maintenance work.

In general, section limits have been established by giving each gang an equal mileage of main line with whatever auxiliary tracks come between these limits. The gangs are then allowed an equal number of men. The result is that some gangs have much more work to perform than others because of unequal mileages of sidetracks and special local conditions. With an unequal distribution of the work, it is evident that the greatest return is not being secured from the total expenditure and loss occurs.

The importance of equating sections on a more equitable basis has been recognized for years and some study has been given to its solution. As a result, certain more or less arbitrary ratios have been established on a few roads, and while perhaps crude and inaccurate, are a step in advance of the common practice.

Thus, on the New York Central two miles of sidetracks, or 15 switches, are considered equivalent to one mile of main track. Allowance is also made for special local conditions, such as soft subgrade, high rock cuts, excessive curvature, character of traffic, etc. An ordinary section is given about six equated miles of main track.

On the Southern Pacific two miles of branch lines, or four miles of sidings, are considered equivalent to one mile of main line. Sixteen

switches are also considered equivalent to one mile of track of the kind in which the switches are placed. Consideration is also given to the nature of the rail, ballast, curvature, density of traffic, etc.

On the Cleveland, Cincinnati, Chicago & St. Louis track sections have been equated where the line has been double-tracked, the length of such sections being made equivalent to six miles of single track on the following basis: Second track, 85 per cent. of main track; passing tracks, 50 per cent. of main track; yard tracks in heavy terminal yards, 50 per cent.; other sidetracks, 30 per cent.; turnouts, each equivalent to 300 ft. of main track.

On the New York, New Haven & Hartford a mile of main track has been taken as a unit. Two miles of sidetrack, or 15 switches, are considered equivalent to one mile of main track. The various lines of this road have been classified between main line, secondary main line, and branches, partially on the basis of the tonnage passing over them and in part on the importance of the lines from a passenger standpoint where the tonnage alone is not sufficiently heavy to bring them into what is considered the proper class. Different allowances of men per equated track mile are made on the lines of these different classes, consideration being given to the fact that on divisions of two and four tracks the shorter distance sectionmen have to go compensating them slightly for the heavier traffic.

An equation was worked out on one division of the Michigan Central about five years ago, covering 300 miles of single main track and 500 miles of branch tracks and sidings. As the result of a 12 months' study of the actual distribution of work on this division, the following relations were established, one mile of single main track being considered as the unit:

One mile of single main main track, Class "B"	100	per cent.
One mile of single branch track	65	" "
One mile of passing track	46	" "
One mile of yard track	32.4	" "
One mile of industrial track	24	" "
One main track turnout	3.4	" "
One side track turnout	1.4	" "
One railroad crossing (one track crossing only)	3.1	" "
One highway crossing (highway over one track)	2.0	" "
One mile of fence (one side)	2.7	" "
One mile of right-of-way (100 ft. wide)	4.2	" "
One farm crossing (over one track only)	0.4	" "

On the Toledo division of the Pennsylvania Lines West of Pittsburgh, consisting almost entirely of single track, with only a small amount of second track, one mile of main track is considered equivalent to three miles of sidetracks, four miles of yard tracks, 20 main line turnouts, 40 turnouts in side and yard tracks, 25 railroad crossings, 40 public highway crossings and 60 private crossings.

The Baltimore & Ohio has given careful attention to the subject of equating track sections in connection with the development of its stand-

ard track work system, as the determination of standard performances is essential to the computation and payment of bonuses. The details of this system, including the determination of units of track work, were described in a monograph by Earl Stimson, published in the Proceedings of this Association for 1916.

The Grand Trunk has given careful consideration to this problem. Based upon its extended studies, the following basis has been approved for equating track forces:

2	miles of passing track	=	1 mile of main track
2½	miles all other sidings	=	" " " "
15	switches	=	" " " "
24	single derails connected with tower or switch stand	=	" " " "
12	single track railway crossings	=	" " " "
15	single highway crossings (public roads)	=	" " " "
10	single highway crossings (city streets)	=	" " " "

STANDARD FORCE.

Class.		Force—1 Foreman and	Equiv. mileage of section.	Men per mile with foreman.	Men per mile without foreman.	Miles per man with foreman.	Miles per man without foreman.
A. Double track lines	S	6 men	9	0.78	0.67	1.29	1.50
	W	3 men		0.44	0.33	2.25	3.00
A. Single track lines	S	4 men	6	0.83	0.66	1.20	1.50
	W	3 men		0.66	0.50	1.50	2.00
B. Single track lines	S	4 men	7	0.71	0.57	1.40	1.75
	W	3 men		0.57	0.43	1.75	2.33
C. Single track lines	S	3 men	8	0.50	0.37	2.00	2.67
	W	2 men		0.37	0.25	2.67	4.00

Each supervisor has a permanent extra gang on his district, based on the following percentage of the actual main line and siding mileage (not equated):

Class A	Summer	10 per cent.
	Winter	5 per cent.
Class B and C	Summer	6 per cent.
	Winter	3 per cent.

CLASSIFICATION OF TRACK.

Class A—Railways having more than one track, or a single track with the following traffic per mile:
Freight cars per year = 150,000 or 5,000,000 tons.
Passenger cars per year = 10,000.
Maximum passenger speed of 50 miles per hour.

Class B—Single track lines having the following traffic per mile:
Freight cars per year = 50,000 or 1,670,000 tons.
Passenger cars per year = 5,000.
Maximum passenger speed of 40 miles per hour.

Class C—Single track lines not meeting the minimum requirements of class B.

An analysis of the cost of maintenance of way and structures for the purpose of establishing the proper relations between expenditures per mile of line and per unit of track for different classes of roads has been made recently for six sub-divisions of one of the roads represented on the Committee. As Sub-Committee (4) of this Committee is reporting on the former phase of this problem the entire analysis is published with that report.

Starting about four years ago the Track Committee undertook the compilation of data showing the actual distribution of the work on a number of representative sections on different roads in various parts of the country. On the organization of the Committee on Economics of Railway Labor this work was transferred to it and this Committee has continued to receive and to study the reports sent in monthly by those roads which are coöperating in the collection of the data. As the consideration of these reports has progressed, the Committee has become convinced of the impossibility of its making a proper analysis of the statistics because of the many local factors which are present on an individual road and which affect the results to a marked degree. The Committee, therefore, believes that the reports of the test sections should be returned to the individual roads for analysis and for the development of the correct formulas. The Committee has found it impossible to furnish and establish uniform formulas because of these local variable factors.

Twenty-one railroads volunteered originally to compile this record. On account of war and other conditions, all but four railroads have discontinued sending in this data.

Appendix B.

(3) TYPICAL PLANS FOR HOUSING LABOR.

A. F. Blaess, *Chairman;*
W. H. Hoyt,
E. D. Jackson,
W. R. Hillary,
John C. Nelson,
J. W. Pfau,
Sub-Committee.

(3) Your Committee reports progress, having prepared and presenting for consideration the following tentative typical plans for housing maintenance of way labor:

1. Knockdown Portable Bunk House—8 men..Floor Plan and Section
2. Knockdown Portable Bunk House—16 men..Floor Plan and Section
3. Septic closet for use with knockdown or permanent camp ....Floor Plan and Section

Camp Cars.

4. Sleeping Car ....Floor Plan Only
5. Foreman's and Commissary Car ....Floor Plan Only
6. Kitchen Car ....Floor Plan Only
7. Dining Car ....Floor Plan Only
8. Material Car ....Floor Plan Only

Knockdown Camps.

9. Washroom and toilet building ....Floor Plan and Section
10. Mess Hall ....Floor Plan and Section
11. Bunk House ....Floor Plan and Section
12. Lounging Building ....Floor Plan and Section
13. Commissary Store ....Floor Plan and Section
14. Isolation Building ....Floor Plan and Section

Permanent Camps.

15. Commissary Store ....Floor Plan and Section
16. Isolation Building ....Floor Plan and Section
17. Mess Hall ....Floor Plan and Section
18. Bunk House ....Floor Plan and Section
19. Lounging Building ....Floor Plan and Section
20. Washroom and Toilet Building..............Floor Plan and Section

The units for 8 to 16 men are intended for isolated places where it is desired to enlarge the gang and where other accommodations for laborers are not available, such as section headquarters at out-of-the-way places.

The septic closet is intended for use in connection with any of the above plans, except the camp cars, which are usually moved too often to justify construction of elaborate facilities. The pit can be made of timber or concrete, according to the length of time it is expected to be used. The building can be readily moved and only the pit is stationary.

The camp car outfits are for gangs frequently moving. The question of ceiling or lining the cars will depend upon the class of labor and the locality, but the Committee feels that the prevailing idea should be to make the quarters for the men comfortable and as attractive as consistent.

Some considerations regarding cast-iron and steel pipes, p. 50-72. 1914. London. Longmans. 142 pp.

The nature and extent of external loads to which pipes and hollow cylinders are subjected and must be capable of carrying without danger of collapse.

United States Cast Iron Pipe and Foundry Company.

Cast-iron pipe in all regular sizes, p. 19, 42, 43. 1914. Barlington.

Cites numerous cases where water is conveyed from reservoirs through cast-iron pipes, and method of calculating superimposed load in order to insure safety.

1915—Conant, E. R.

Load tests of concrete pipe. 1915. (In Engng. News, v. 74, p. 556-557.)

Details and results of testing concrete pipes by external loading.

Etcheverry, B. A.

Irrigation practice and engineering; vol. 2, conveyance of water, p. 241-242. 1915. New York. McGraw. 3 vols.

Formula for stress produced by weight of backfill over pipe.

Greathead, J. F.

Soil tests reported and safe underpinning methods in sand described. 1915. (In Engng. Rec., v. 72, p. 631-633.)

Experiments to determine the greatest imposed load a certain sand would safely stand without undue or progressive settlement, also diagram showing distribution of vertical soil pressure.

Moyer, J. A.

Distribution of vertical soil pressures. 1915. (In Engng. Rec., v. 71, p. 330.)

Gives results of experiments made at Pennsylvania State College.

1915—Pile driving destroys a tunnel by clay pressure. 1915. (In Engng. News, v. 74, p. 404-405.)

Nowhere had a pile actually touched the tunnel; the damage was caused wholly by the crowding pressure of the clay.

Schlick, W. J.

Tests of some large reinforced concrete culvert pipe. 1915. (In Concrete Cement Age, v. 6, p. 78-80.)

Pipes were tested to failure with sand boxes on top of pipe; the data show that the safe load for these pipes was somewhat less than one-half the maximum load; however, the series of tests is so limited that no general conclusions can be drawn.

Smith, W. M.

Arch reinforced concrete conduits designad by the theory of least work. 1915. (In Engng. Rec., v. 71, p. 648-653.)

Method of finding earth pressure on arch conduits through earthen embankments.

1916—Enger, Melvin L.

High unit pressures found in experiments on distribution of vertical loading through sand. 1916. (In Engng. Rec., v. 73, p. 106-108.)

Results indicate practically no decrease in maximum intensity of pressure with an increase in bearing area.

Same. Experiments on the distribution of vertical pressure through sand. 1916. (In Railway Rev., v. 58, p. 129-132; Railway Age Gaz., v. 60, p. 321-323.)

Fehr, B. R., and C. R. Thomas.

Results of some tests to determine the distribution of vertical pressure through sand. 1916. (In Engng. Contracting, v. 45, p. 306-309.)

Gives illustration of two types of apparatus used in making tests, also results of tests showing percentages of loads transmitted through sands.

Goldbeck, A. T., and E. B. Smith.

Apparatus for determining soil pressures. 1916. (In Proc. Amer. Soc. Testing Materials, v. 16, p. 310-319.)

Description of method used for testing distribution of pressures through earth fills.

Abstracts. Apparatus for determining soil pressures devised. 1916. (In Engng. Rec., v. 74, p. 48.) Soil pressure measuring device. 1916. (In Engng. and Contracting, v. 46, p. 180-181.) Device to test soil pressure. 1916. (In Engng. News, v. 76, p. 339.)

Miller, M.

Test earth pressures in subway excavation. 1916. (In Engng. Rec., v. 74, p. 291.)

Deflection measurements on timber rangers and computed values of pressures up to 50-foot depths reported.

1916—Sackett, R. L.

Distribution of vertical pressure through sand. (Letter.) 1916. (In Engng. Rec., v. 73, p. 398.)

Discussion on experiments by Melvin L. Enger.

1917—Fehr, R. B.

Distribution of pressure in earth due to concentrated external loading. 1917. (In Engng. Contracting, v. 47, p. 480-482.)

Determination of the distribution of vertical pressures transmitted from an externally applied load through various depths of soil.

Fowler, G. L.

Tests of corrugated culvert pipe under a sand bed. 1917. (In Railway Gaz., v. 26, p. 687-691.)

Investigations of the behavior of culverts under external loading.

Brief abstract. 1917. (In Jnl. Amer. Soc. Mech. Engrs., v. 39, p. 737-738.)

Goldbeck, A. T.

Distribution of pressures through earth fills. 1917. (In Proc. Amer. Soc. for Testing Materials, v. 17, p. 641-661.)

Results of soil-pressure measurements made with the aid of an apparatus already described before this Society. Gives mechanical analysis of sand used in tests and application of results, with discussion.

Abstracts. 1917. (In Good Roads, no. s., v. 14, p. 79-81; Engng. and Contracting, v. 47, p. 589-590.) How are vertical loads distributed through earth-fills? 1917. (In Engng. News, v. 79, p. 116-117.)

Undercrossing wing wall designed to limit base pressure. 1917. (In Engng. News, v. 79, p. 1054-1055.)

Calculations for earth pressure over culvert and method of limiting it.

Marston, A.

The Supporting Strength of Sewer Pipe in Ditches and Methods of Testing, etc. (Bulletin No. 47, Iowa State College of Agriculture and Mechanic Arts Experiment Station, October 10, 1917.)

Appendix B.

DEPOSITING CONCRETE UNDER WATER.

G. E. Boyd, Chairman, Sub-Committee.

This subject was assigned to the Masonry Committee for report at the 1912 convention, and considerable work was done in the way of procuring data from the members and compiling same. Certain conclusions were reached and were adopted by the Association for publication and appear on pp. 293 and 294 of the 1915 edition of the Manual. The Committee feels that these conclusions require revision.

In view of the unsettled conditions during the past season it was not thought desirable to attempt to go over the ground in this way at this time, and this report is presented with the hope that it may promote discussion and result in additional information on means used and results obtained from various methods of depositing concrete under water. The Committee in making its report does so with the recommendation that this subject be again assigned for consideration next year, as it does not feel that any definite conclusions cvan be presented to the Association at this time. There is, however, some data which the Committee believes it is desirable to present to the Association as representing in its opinion the best practices to be followed in depositing concrete under water.

1. In general, where it is possible, the depositing of concrete under water should be avoided, even if such action results in additional expense and possible delay to the work. There is always considerable uncertainty as to the results obtained where concrete is deposited under water, and the Committee believes that where conditions will permit, the additional expense and delay of avoiding it is well warranted.

2. In view of this uncertainty, the need of close supervision by men competent to handle this class of work is of the utmost importance, and concrete should never be deposited under water without experienced supervision. Many failures which have occurred in concrete deposited under water, especially where the structure is located in sea water, can be directly traced either to ignorance or lack of supervision. Frequently the work is done under the supervision of men inexperienced in this class of work rather than to go to the expense of hiring capable men.

Of the methods used, the following seem to give the best results:

1. The concrete is lowered in large buckets having a hinged bottom which sets sufficiently far above the lower edge of the bucket so that it may open freely downward when the bucket reaches the surface upon which the concrete is to be deposited. The top of the bucket is left open, and care is taken to see that the bucket is completely filled before lowering. Efforts made to use a closed top bucket have not been successful, due to the disturbance of the deposited concrete by inrush of water as the bucket is withdrawn.

2. The concrete may be passed through a vertical tube or tremie reaching down to the surface upon which the concrete is to be deposited. In this case the tube should be kept filled with concrete at all times, and the flow should be as nearly continuous as practicable.

3. Jute or cloth bags, from two-thirds to three-fourths filled, have been used successfully. These are placed in a header and stretcher system so that the whole mass is interlocked.

4. Where it is difficult to construct a cofferdam or monolithic work is not required, premolded concrete blocks of large dimensions have been used successfully.

5. A concrete depositing bag made of canvas or other suitable material is a variation of the bucket system. This is filled and the mouth of the bag closed by one turn of a line so looped that a pull on the line will release it. The bag is lowered mouth down to the surface upon which the concrete is to be deposited, and a sharp pull on the line opens the bag and permits the concrete to be deposited. This method does not have the disadvantage of the closed top bucket, since the bag will collapse as the concrete flows out.

There are a number of other methods that have been used, such as depositing directly through the water; depositing a portion of the concrete by one of the above methods in the corner of the form and the balance progressively from wheelbarrows or buckets on the sloping surface, thus gradually filling the form; allowing the concrete to partially set in air and then depositing it in a plastic condition; depositing the concrete dry without the use of water; attempting to grout a foundation composed of riprap or coarse gravel by means of pipes sunk at intervals into the foundation. Although occasionally fair results have been obtained, all of these methods are dangerous, as they almost uniformly result in segregation of the materials or the washing out of the cement.

Depositing With Drop Bottom Buckets.—The drop bottom bucket should be so arranged as not to discharge the load until the bucket reaches the surface upon which the concrete is to be deposited. In lowering the bucket, care should be taken that unnecessary wash is not produced. This may be avoided by slowing up the operation when the bucket is passing through the water. The bucket, when the load is discharged, should be withdrawn slowly until clear of the concrete. In depositing concrete under water by this method it is imperative that the work be continuous and sufficiently rapid to insure bonding of the successive layers. By this means the laitance formed can be brought to the finished surface and later removed after the concrete has hardened. There are a number of other types of buckets, such as the tipping bucket or bottom dumping bucket. The use of all these should be avoided, as they tend to stir up the material and wash out the cement.

Depositing Through Tremie or Vertical Tubes.—This device should be about 14 inches or 16 inches in diameter, made up in sections so that the length may be adjusted to the depth of the water. The joints should

be made flanged and the tube put together with gaskets, in order to avoid leakage of the water into the tube. The top should be flared, in order to receive the concrete properly. The tube should be suspended in such manner that it may be moved laterally as required. The upper end is placed near the level of the working platform, while its lower end rests on the surface upon which the concrete is to be deposited. When the operation starts the tube should be filled in such manner that the concrete is not permitted to drop down through the water. This is accomplished in several ways: One is to place the bottom of the tube in a box, partially filling it with concrete so as to seal the bottom, then lowering the box into the position in which it is to be used. Another method is to plug the tube with cement sacks or other material, which will be forced down as the tube is filled with concrete. In both these methods undesirable material is introduced into the concrete, but if the area to be covered is large this is a matter of minor importance. However, the first deposits from the tube should be kept away from the edge of the work. One requisite of this method is that the tube must at all times be kept filled with concrete and the greatest care exercised to see that the charge is not lost in moving it about the bottom. In case it is lost, the tube should again be filled as at first. One of the disadvantages of this method is that unless the greatest care is exercised, it is almost impossible to avoid losing the charge occasionally. This will depend very largely on the quality of the supervision exercised over the work. Another disadvantage of this method is that the area over which it can be used is limited, and if it is necessary to deposit concrete over a large area a number of tubes should be used. With this method, as with all others, it is desirable that the concrete be deposited continuously from the time the work is started until it is brought above the water level or to the finished surface, which can later be cleaned in the air after the concrete has hardened.

Considerable difference of opinion exists among Engineers as to whether the concrete to be deposited by this method should be made wet or dry. In the first case the concrete is made quite wet and the bottom of the tremie submerged several feet below the surface of the concrete as deposited. The material is allowed to flow out of the tube and seek its own level. In depositing the concrete dry, just sufficient water is used to make it plastic and the concrete is distributed by moving the foot of the tremie over the surface. Good results apparently have been obtained from each of these methods, but the opinion of the Committee is that the dry method is preferable. If the concrete is deposited wet considerable difficulty is encountered in keeping the tremie full and more or less segregation of the materials is bound to occur. It is extremely difficult to move the tube where sufficiently submerged in the concrete to permit the wet concrete being used.

Bagging Method.—While the bagging method insures good concrete and will prevent the formation of laitance, it is open to the objection that a monolithic foundation is not secured. Where, however, the walls

of the foundation formed by the bags will not be exposed to scour, the Committee is of the opinion that the method will give satisfactory results. This method can be used to advantage in sealing the foundations of cofferdams where it is impracticable to prevent inflow of water through crevices in the bottom. In using this method it must be borne in mind that satisfactory results cannot be obtained unless the bags are carefully placed by hand, and this makes the service of a diver necessary except where placed in very shallow water.

Premolded Concrete Blocks.—Premolded concrete blocks can be used to advantage on a prepared foundation in large structures such as breakwaters, bulkheads, lighthouse foundations, seawalls—any heavy construction where the units can be large enough not to require bonding. The blocks are usually molded in the air in units weighing from 15 to 20 tons, and are deposited in place by the use of derricks.

Materials and Mixing.—Concrete to be deposited in water should be of a richer mixture than when deposited in air, and a leaner mixture than 1-2-4 should not be used. It is the opinion of the Committee that only so much water should be used as will make the concrete of a plastic consistency. Very dry concrete is as undesirable for this purpose as wet concrete. It is the opinion of the Committee that washed gravel of somewhat smaller size than used in the open air concrete will give the best results. This is particularly true where the tremie method is used. The sand should be free from loam and other material, and it is preferable that washed sand be used where possible to obtain it. The aggregate should be capable of producing dense concrete, and it is recommended that tests be made of the materials available to determine the best aggregate for this purpose.

Precautions.—In depositing concrete under water it is imperative that the water be still and that the concrete shall not be exposed to current until it is fully set. This requires that a cofferdam be constructed in such manner as to insure quiet water within the cofferdam. One of the essentials of depositing concrete by any of the above methods is that the concrete be disturbed as little as practicable during the depositing, thus avoiding the formation of laitance. It is impracticable in depositing concrete in water by any method to entirely avoid laitance, and it is therefore necessary on completing a section of concrete to see that the laitance is entirely removed after the concrete has thoroughly set and before the work is resumed. For this reason it is the opinion of the Committee that when a job is started the concrete should be deposited continuously until the finished surface is reached or the concrete brought above the water level so that the laitance may be removed in the air, as it is difficult, if not impracticable, to entirely remove it under water. The formation of horizontal construction joints under water should be avoided.

The ordinary precautions used in depositing concrete in the air are not sufficient when depositing concrete in water, and additional care must

be observed in the latter case to prevent segregation of the materials, the formation of laitance, and to insure proper setting of the mass. Because of the fact that cold retards setting, the concrete should not be deposited in water the temperature of which is low enough to cause serious retardation. Concrete should be thoroughly mixed before it is deposited in water and, therefore, hand mixing should never be permitted, but a batch mixer used.

Appendix C.

REPORT ON DISINTEGRATING OF CONCRETE AND CORROSION OF REINFORCING MATERIALS IN CONNECTION WITH THE USE OF CONCRETE IN SEA WATER.

J. J. YATES, Chairman, Sub-Committee.

Your Committee has confined itself to a careful examination of publications bearing on the subject of concrete and reinforced concrete in sea water. About seventy publications were reviewed, thirty-nine of which have been selected as the best references on the subject, and are herein submitted to the members as information.

The Committee is not prepared to give any conclusions or to make any recommendations on the subject, but requests a reassignment, so that the investigation may be continued.

Action of the Sea on Concrete; by Coignet.
Am. Soc. Civ. Eng., Vol. I, 1871, p. 110.
Statements on the physical and chemical action of the sea on concrete. Concludes that impervious carbonate surface coat is formed, which if not broken will protect the interior concrete from the chemical action of sea water.

The Influence of Sea Water on Mortars; by E. Candlot.
Engineering Record, November, 1897, p. 557.
A digest of experiments and observations made in France over a period of forty years, under conditions adapted closely to practice; also discussion of other experiments.

An Example of the Decomposition of Concrete in Sea Water.
Engineering News, August 27, 1908, p. 238.
Description of the disintegration of dock wall at Charleston Navy Yard, Boston Harbor. (Illustrated.)

Examples of Tidal Injury to Concrete; by Tyrell Slurtzer.
Engineering News, October, 1908, p. 453.
Describes the action of sea water on concrete at Portland, Me.

Effect of Sea Water Upon Concrete; by Edwin Thacher.
Trans. Am. Soc. Civ. Eng., Vol. XLI, December, 1908, p. 42.
Gives a comparison of American and foreign practice.

Reinforced Concrete Pier Construction; by Eugene Klapp (with discussion).
Am. Soc. Civ. Eng., Vol. LXX, 1908, p. 448.
Description of materials used in construction of concrete piers.

Discussion of the Effect of Alkali on Concrete; by G. C. Anderson.
Am. Soc. Civ. Eng., Vol. LXVII, 1910, p. 572. Discussion by R. L.

Humphrey, Vol. LXVII, June, 1910, p. 598.
Described experiments made at Atlantic City, N. J.

Methods of Employing Concrete in Sea Water and Examples of Typical Marine Structures of Concrete; by Chanlar Davis.
Engineering and Contracting, August 31, 1910.

Abstract of paper read at convention of National Association of Cement Users. (Illustrated, 4,000 words.)

Detail Report of Aberthaw Construction Company Tests at the Charleston Navy Yard, Boston.
Cement Age, October, 1911.

Reinforced Concrete in Hydraulic Works; by John Sewell.
Engineering News, Vol. LXVII, May 30, 1912, p. 1029.
Papers No. 30-34 presented to the International Congress held in Philadelphia, Pa., May 23-27, 1912, by Richard L. Humphrey, M. Jacqimot, R. W. Vawdrey, Hungarian State Water Survey, and M. Mederico Perilli, respectively, are reviewed and summarized under the following headings: Durability of concrete; resistance to abrasion; resistance to chemical action; freezing in contact with water and conclusions.

Destruction of Concrete between Tides in Sea Water; by Wm. B. Mackensie.
Engineering News, Vol. LXVIII, July 4, 1912, p. 28.
A discussion of review made by John S. Sewell, published in Engineering News, Vol. LXVII, May 30, 1912, p. 1029, referred to above.

Alkali Action on Concrete, Investigation by the U. S. Reclamation Service; by J. Y. Jewett.
Engineering Magazine, Vol. XLIV, November, 1912, p. 267.
An outline of the method of investigation to be made by the Service.

Abstract from report entitled, "Action of the Salts in Alkali Water on Cement"; by P. H. Bates, A. J. Phillips and R. J. Wig.
Technologic papers of the Bureau of Standards No. 12, November 1, 1912.
The report, which consists of 157 large pages, is covered in a general summary, which includes 16 tentative conclusions. These are based on results of experiments covering three and one-half (3½) years at Atlantic City, N. J.

Action of Alkali and Sea Water on Concrete.
Engineering News, Vol. LXX, July 10, 1913, p. 50.
The U. S. Bureau of Standards Report.

Four Year Test of the Effect of Sea Water on Concrete.
Engineering News, Vol. LXX, November 20, 1913, p. 1023.
A description of the test piles made by the Aberthaw Construction Company after four years' exposure to sea water at Boston, Mass.

Action of Sea Water on Concrete, Six Year Test of 23 Moulded Piles; test conducted by the Aberthaw Construction Company.
Engineering Record, Vol. LXIX, March 21, 1914, p. 344.
Gives large photographs of test piles which show clearly the action of the sea water, with the notes covering each specimen.

Results of Tests to Determine the Action of Sea Water on Concrete.
Engineering and Contracting, Vol. XLI, May 6, 1914, p. 516.
Aberthaw Construction Company tests.

Account of Tests of the Action of Sea Water on Concrete.
Concrete-Cement Age, June, 1914, p. 273.
Report on the test specimens of the Aberthaw Construction Company at Boston, Mass.

Factors Controlling the Durability of Concrete in Sea Water; by F. W. Huber.
Western Engineering, November, 1914.

Explains the chemistry of the action of sea water upon concrete; discusses failures, successful work and remedies proposed to improve cement for this use.

Disintegration of Concrete and Corrosion of Reinforcing Metal.
Am. Ry. Eng. Assoc., Vol. XV, 1914, p. 564.
Includes a discussion of concrete in sea water with conclusion.

Some Experiences with Concrete in the Republic of Panama; by Alex P. Crary.
Engineering News, February 4, 1915.
Gives effect of sea water on concrete. (Illustrated, 2200 words.)

Reinforced Concrete Docks; by H. S. Taft.
Am. Soc. Civ. Eng., Vol. LXXVIII, 1915, p. 1058.
Foreign and American structures, failures, costs and general considerations, with discussion.

Reprint of Report on the Destructive Action of Sea Water on Concrete and Methods of Guarding against it; by W. W. Pagon.
Monthly Journal of the Engineers' Club of Baltimore, April, 1916.
Gives conclusions based on review of subject matter in the Library of the Am. Soc. Civ. Eng.

Characteristics Required of Concrete to Resist Action of Sea Water; by W. W. Pagon.
Engineering and Contracting, May 24, 1916; Engineering Record, Vol. LXXIII, May 27, 1916, p. 702; Concrete, Vol. IX, October, 1916, p. 112.
Conclusions submitted after a careful study of the various articles dealing with the action of sea water on concrete.

Qualities Required of Concrete to Resist the Action of Sea Water; by W. W. Pagon.
Engineering and Mining Journal, July 29, 1916, p. 102.

Bad Effects Resulting from the Use of Salt Water in Reinforced Concrete Structures Built in Tropical Countries; by J. L. Harrison.
Engineering and Contracting, Vol. LXVI, November 22, 1916, p. 443; Engineering News, Vol. LXXVI, November 30, 1916, p. 1047. (Abstract.)
Review of many structures in the Philippine Islands. Concludes that the cause of cracking and failing of reinforced concrete structures is due to use of salt water, porous concrete, chlorine in air, or all combined.

The Effect of the Use of Salt Water for Gaging Concrete on the Life of the Reinforcing Steel Embedded therein; by J. L. Harrison.
Monthly Journal of the Engineering Club of Baltimore, December, 1916.
Concludes that the gaging of concrete with salt water in the Philippine Islands was dangerous. (Illustrations.)

Tests of Concrete Specimens in Sea Water at Boston Navy Yard; by R. E. Bakenhus.
Transactions Am. Soc. Civ. Eng., Vol. LXXXI, December, 1917, p. 645.
A report of the behavior of the twenty-four test pieces made by the Aberthaw Construction Company after having been exposed to the sea water for seven years. Also discussion. (Illustrated, 2000 words.)

The Effect of Sea Water on Some of the Concrete Structures in the Philippine Islands; by J. L. Harrison.
Engineering and Contracting, June 27, 1917.
Concludes by chemical analysis of specimens taken from various structures in the Philippine Islands that chemical action does take place in tidal tropical water. (Illustrated, 2000 words.)

Public Works of the Navy, Bulletin 27, July, 1917; Bulletin 28, October, 1917.

Report submitted by the Bureau of Standards to the Bureau of Yards and Docks of the Navy Department, covering investigation of the action of sea water on concrete.

What Is the Trouble with Concrete in Sea Water; by Rudolph J. Wig and Lewis R. Ferguson.

Engineering News Record, Vol. LXXIX, September 20, 1917, p. 532.

First of a series of five papers on the deterioration of concrete in sea water. Reports are based on an examination of 146 structures in the United States, Canada, Cuba and South America. (Illustrated, 2000 words.)

Plain Concrete in Sea Water Must Be Protected against Abrasion; by Rudolph J. Wig and Lewis R. Ferguson.

Engineering News Record, Vol. LXXIX, October 4, 1917, p. 641.

The second of a series of five articles.

Reinforced Concrete in Sea Water Fails from Corroded Steel; by Rudolph J. Wig and Lewis R. Ferguson.

Engineering News Record, Vol. LXXIX, October 11, 1917, p. 689.

The third of a series of five articles stating that "Percolation of salt water or salt air to reinforcing steel causes rusting with subsequent expansion and resulting failure of structure; remedies are difficult to find." (Illustrated.)

Selection of Materials for Sea Water Concrete; by R. J. Wig and Lewis R. Ferguson.

Engineering News Record, Vol. LXXIX, October 18, 1917, p. 737.

The fourth of a series of five articles, stating that "Any standard Portland cement may be considered safe as may also sea water gaging; great care should be exercised in choosing aggregate." (Illustrated.)

Good Workmanship Necessary to Make Sea Water Concrete Safe; by R. J. Wig and Lewis R. Ferguson.

Engineering News Record, Vol. LXXIX, October 25, 1917, p. 794.

The last of a series of five articles stating that "Correct proportions, judicious use of water, tight forms, a good contractor and efficient inspection are needed to bring concrete to proper condition to resist sea water action." (Illustrated.)

Spalling of Reinforced Concrete in Moist Locations; by F. E. Turneaure.

Engineering News Record, Vol. LXXX, January 3, 1918, p. 46.

States that "Spalling is due to alternate wetting and drying of concrete." (Illustrated.)

Comment on the Behavior of Sea Water Concrete.

Engineering News Record, Vol. LXXX, February 7, 1918, p. 264, and March 21, 1918, p. 575.

A discussion of the articles on concrete in sea water which were written by R. J. Wig and Lewis R. Ferguson.

Are Spirally Wound Concrete Piles Safe in Sea Water; by A. C. Chenowith.

Engineering News Record, Vol. LXXX, May 9, 1918, p. 926.

A short discussion of Chenowith piles with reference to the articles published in Engineering News Record during September and October, 1917.

Effect of Sea Water on Concrete.
Concrete, Vol. XIII, July, 1918, p. 35.
Points out the need for careful determination to provide against the probable action of sea water on concrete hulls of ships.

Reinforced Concrete in Harbor Works; by A. F. Dyer.
Canadian Engineer, Vol. XXXV, September 26, 1918, No. 13, p. 277.
Discussion of experience with reinforced concrete in harbor work at Halifax, N. S., extending over a period of several years.

Appendix D.

PREPARE SPECIFICATIONS FOR SLAG AGGREGATE.

W. S. LACHER, Chairman, Sub-Committee.

After a study of the data available on the properties of slag and of specifications for slag as an aggregate in concrete, your Committee does not feel warranted in submitting a specification for adoption by the Association. The following discussion of this subject is submitted as information. This applies to the use of slag as the *coarse* aggregate only.

The Committee believes that the general requirements for coarse aggregates for use in concrete as specified in paragraph 4, page 282, of the Manual, may be applied to blast furnace slag without modification.

Further requirements for slag in current specifications examined cover such matters as origin, method of cooling, age, weight, strength and chemical limitations. At the end of this report a table is presented which lists the requirements of ten specifications for slag to be used in concrete and which demonstrates a marked lack of uniformity. We offer the following comments:

As to origin, only two specifications definitely called for blast furnace slag, all others read so as to permit the products of the steel furnace as well as the blast furnace.

Air cooling is general and represents the type of material desired. This can be required without causing any commercial difficulties. When it comes to the matter of age or time of seasoning, the case is not so clear and the requirements vary. Some specifications demand a year's seasoning, others permit the use of the material after two or three weeks. The necessity for this depends on the nature of the slag. According to Sanford E. Thompson, a limestone slag (one containing only 1 to 2 per cent. of magnesia) is not stable until seasoned for considerable periods, while a magnesia slag (one containing 4 per cent. or more of magnesia) is commonly used within two or three weeks after banking, as no chemical change is apparent on exposure.

The weight is the most definite requirement and concerning which there is the greatest uniformity. Seventy pounds per cu. ft. would seem to be a conservative yet reasonable figure.

Strength requirements are considered as impractical and without adequate precedent. Those discovered apply only to materials to be used in pavements where resistance to abrasion or surface impact is important.

Chemical limitations are placed in specifications for slag presumably to exclude materials containing unstable compounds or elements of a disintegrating or corrosive nature. The content of sulphur receives the widest attention in this regard and the limitation has been variously stated at from 1 to 2 per cent. where it is covered in the specification.

The presence of unslaked lime seems to be of more vital importance since the presence of this material would obviously tend toward unsound-

ness of the slag on exposure to moisture unless neutralized by acid ingredients. It is because of this that some specifications place the limitations on the lime content and specifiy a minimum amount of silica to insure that enough of the SiO_2 radical shall be present to stabilize the CaO. As some users of slag are of the opinion that the seasoning of the material in a bank exposed to the weather would insure the elimination of any free lime and as there appear to be no test data available tending to demonstrate the adequacy and efficacy of these chemical requirements for sulphur, lime or silica, the Committee does not feel qualified to make any definite recommendation in this regard.

In using slag in concrete it is necessary to include a requirement in the specification for the concrete that will insure proper proportions. Very strong concrete may be made with slag if the proportion of cement and fine and coarse aggregates are such as to provide high density, but owing to the porous nature of most slags, somewhat larger quantities of cement and fine aggregate will be required to obtain the desired density than is the case of most ordinary materials used as coarse aggregates.

Specification Requirements for Slag.

Authority	Strength	Origin	Air Cooled	Age	Weight lb. per cu. ft.	Sulphur Not Over	Lime, Not Over	Silica, Lot Less Than
New York Central..........	....	Blast Furnace	Yes	2 mo.	70	1.7%*	48%	33⅓%
Sanford E. Thompson......	....	....	Yes	....	65†	1.7%	48%	32%
Central of Georgia	....	....	....	1 yr.	....	....	....	....
Viaduct Cuyahoga County, Ohio..........	‡		....	....	74	....	....	....
Bldg. Spec. Philadelphia..........	....	Blast Furnace	Yes	....	75	1.3%	....	....
Ohio State Highways.. A	Toughness not less than five	....	....	....	70	1.5%	45%	32%
Ohio State Highways.. B	Toughness not less than five	....	....	....	65	2.0%	45%	32%
Ohio State Highways... C	....	....	....	....	....	2.0%	45%	30%
Youngstown City Engineer..........	....	....	Yes	Lime slag 3 months Mag. slag less	68	....	....	....
U. S. Department of Agriculture...	....	....	....	....	70	....	....	....

*No free sulphur, chemical analysis every 2,000 cu. yd.
†After shaking to refusal.
‡Abrasion loss not more than ten. Factor of hardness not less than twelve. Factor of toughness not less than six.

A series of tests made by Professor D. A. Abrams at the Structural Materials Research Laboratory, Lewis Institute, Chicago (not heretofore published) show the importance both on the wearing qualities and strength of proper storage during the early hardening period. The results of these tests, which are made a part of this report, indicate that with small speci-

mens a few days' moisture is helpful to the strength and wearing qualities, while provision for moisture for several weeks will produce results almost equal to those which would be obtained with continuous favorable storage conditions.

While the results on small specimens only approximate the results to be expected where large masses of concrete are used, it is not unreasonable to assume that particularly where the concrete is to be used as a wearing surface, great improvement in the strength and wearing qualities can be obtained by providing moisture to the hardening concrete for several weeks after the concrete is mixed and placed. The usual specifications for concrete roads provide that concrete shall be covered with earth or other similar material and kept moist for two weeks. Floor specifications are also being changed to provide for similar protection. The better floor contractors now cover the newly laid floor with sand and keep the floor sprinkled for from several days to two weeks. A marked improvement in wearing qualities is noticeable. In mass concrete, while provision for moisture is desirable and should be encouraged where practicable, it is not absolutely imperative as mass rather than high strength is sought.

In all reinforced concrete structures, however, some provision should be made to prevent the rapid drying out of the concrete, which almost invariably occurs during the summer months. Many contractors have observed that concrete placed in the early spring and late fall, and many claim in the winter, shows far more satisfactory results than concrete placed in middle summer. This difference, no doubt, arises from failure to provide plenty of moisture to the rapidly hardening concrete in summer. All concrete should be protected from the direct rays of the sun and unless the expense is absolutely prohibitive, sprinkled for from several days to several weeks, depending upon the character of structure.

EFFECT OF QUANTITY OF MIXING WATER AND CURING CONDITIONS ON THE STRENGTH AND WEAR OF CONCRETE.

By Duff A. Abrams.*

Introduction.

The necessity for careful restriction on the quantity of mixing water used in concrete, and the importance of proper curing conditions during the period of setting and hardening are not generally appreciated by engineers and contractors doing concrete work. In view of the widespread use of concrete in the construction of pavements, floors, loading platforms, and in other places requiring high strength and resistance to abrasion, it seemed desirable to carry out an experimental study which would bring out the effect of water content and curing conditions on the compressive strength and the wearing resistance of concrete, and the relation between these two properties.

These tests were made as a part of the experimental studies of the properties of concrete and concrete materials, being carried out through the co-operation of Lewis Institute and the Portland Cement Association at the Structural Materials Research Laboratory, Lewis Institute, Chicago.

This series comprised compression tests of 120 6 x 12-inch cylinders and wear tests on 300 blocks, 8 inches square and 5 inches in thickness. A 1-4 mix was used throughout, that is, 1 volume cement and 4 volumes mixed aggregate. This mix is about the same as the 1-1½-3 or 1-2-3 mixes generally used for concrete which is to withstand high stresses or to form the wearing surface of pavements. Most of the tests were made on sand and pebble aggregates. One group was repeated with crushed limestone as coarse aggregate.

Concrete of six different consistencies was used, each being stored under four different conditions:

(1) Damp sand 4 months, tested damp.
(2) Damp sand 21 days, air 99 days.
(3) Damp sand 3 days, air 117 days.
(4) Air of laboratory for entire curing period of 4 months.

Parallel tests were made throughout on compression and wear. All tests were made at the age of 4 months.

The wear blocks were tested in the Talbot-Jones rattler by the same methods that were used in other tests carried out in this laboratory.†

*Professor in Charge of Structural Materials Research Laboratory, Lewis Institute, Chicago.

†See "A Method of Making Wear Tests of Concrete" by D. A. Abrams, Proc. American Society for Testing Materials, Part II, 1916; also "Effect of Time of Mixing on the Strength and Wear of Concrete," by D. A. Abrams, Proc. American Concrete Institute, 1918.

Acknowledgment is due to the Chicago Gravel Company, Chicago, for their courtesy in furnishing the sand and pebble aggregate used in these tests, and to Dolese & Shepard, Chicago, for the crushed limestone.

Materials.

The Portland cement used in these tests consisted of a mixture of equal parts of four brands purchased in the Chicago market. The brands were thoroughly mixed by placing one sack of each in a concrete mixer and running for about one minute. Complete tests of the cement are given in Table 1.

The aggregates consisted of sand and pebbles from the Chicago Gravel Company's plant near Elgin, Ill., and crushed limestone from Dolese & Shepard Company's quarry. Before using, the sand was screened through a No. 4 sieve. All material coarser than this size was rejected. The sand was used without further screening, but care was taken to see that the material in the bin was thoroughly mixed so that it was uniform throughout the series. Pebbles and crushed limestone were screened to three different sizes (No. 4-⅜, ⅜-¾, and ¾-1¼ inches) and recombined in definite proportions for each batch, as shown by the sieve analyses in Table 2.

The water was from the city water supply obtained from Lake Michigan.

The weights per cubic foot of aggregates were determined by means of machined, cast-iron measures having capacities of ⅒ and ½ cubic foot. The ⅒ cubic foot measure was used for the sand and the ½ cubic foot for the coarse aggregates and the mixed aggregates. The inside diameter of each measure is equal to the depth. The test was made by filling the measure about one-third full and puddling with a ⅝-inch steel bar pointed at the lower end. Filling and puddling were continued in like manner until the measure was full. After striking off with a straight-edge the weight was determined. This is the method recommended by Committee C-9 on Concrete of the American Society for Testing Materials, but the method has not yet been standardized by the Society.

The absorption of the aggregate was determined as follows:

The sand was dried to constant weight and cooled to room temperature in a desiccator. A 500-g. sample was placed in a 500-cc. volumetric flask and the volume of water necessary to fill to mark carefully measured. At frequent intervals the flask was filled to mark. The zero volume was obtained in the same manner, except that the sand was coated with kerosene to prevent absorption of water. This is an adaptation of Rea's method for determining specific gravity of fine aggregates.*

The coarse aggregate was dried to constant weight, cooled to room temperature and weighed, then immersed in water at room temperature.

*See "Apparent Specific Gravity of Non-Homogeneous Fine Aggregates," by A. S. Rea, Proc. A. S. T. M., Part II, 1917.

At frequent intervals it was removed from the water, quickly surface-dried with a towel and weighed. Our experience with these methods indicates that the absorption at about 3 hours gives the best results in estimating the quantity of water necessary for concrete mixes.

Proportioning and Mixing Concrete.

In all the tests included in this report the concrete consisted of a 1-4 mix by volume; that is, 1 volume of cement to 4 volumes of mixed aggregate, considering 94 pounds of cement as 1 cubic foot. This mix is equivalent to the 1-1½-3 or 1-2-3 mixes generally used for one-course concrete road construction. The exact equivalent of our 1-4 mix when expressed in the customary manner will depend on the size and grading of the aggregate.

The concrete was mixed by hand in the manner regularly followed in making such tests in this laboratory. Each specimen was made from a separate batch of about ⅙ cubic foot, which was proportioned separately and mixed with a bricklayer's trowel in a shallow metal pan. This method leaves no uncertainty as to the exact quantities of materials in each specimen.

The term "consistency" as used in this report refers to the plasticity of the concrete; that is, the relative and not the actual quantity of mixing water. It has been found convenient to express the quantity of water used in the concrete in terms of the volume of cement. This so-called water-ratio has been shown to be the best criterion of the strength of the concrete.

The consistency which we have called "normal" (relative consistency = 1.00) is of such a plasticity that a 6 x 12-inch cylinder of 1-4 concrete will "slump" ½ to 1 inch upon removal of the metal form by a steady, upward pull immediately after molding the specimen. Concrete of relative consistency of 1.10 will show a slump of 5 to 6 inches; 1.25, a slump of 8 to 9 inches.

Test Pieces.

This report covers compression tests of 6 x 12-inch concrete cylinders and wear tests on concrete blocks 8 inches square and 5 inches in thickness.

The 6 x 12-inch cylinders were molded in metal forms made of 12-inch lengths of 6-inch inside diameter cold drawn steel tubing, which had been split along one element by means of a thin slotter. The form was closed by a circumferential band. Each form stood on a machined, cast-iron base plate. A thin sheet of paraffined tissue paper was placed between the base plate and the cylinder form.

In molding the cylinder the form was filled about one-third full and the concrete puddled with a ¾-inch steel bar about 21 inches long. Filling and puddling were continued until the form was full. The top was

leveled off with a bricklayer's trowel. About 3 to 4 hours after molding, a thin layer of neat cement paste (which was mixed at the same time or before the concrete) was spread over the top of the cylinder. A piece of plate glass and a sheet of paraffined paper were used to form a cap, which made a smooth, square end for loading. The glass remained in place until the form was removed. This method of capping is much better than setting the specimens in plaster of paris or a cement-plaster mixture immediately before testing. It has the following advantages:

(1) The cap is just as strong and stiff as the concrete and forms an integral part of the specimen.
(2) The time and labor required is a small part of that necessary with the plaster method.
(3) The plate glass prevents evaporation of water during the period the concrete is in the form.
(4) The cylinder is ready for test at any time without further preparation.

The metal forms for the wear blocks were made in gangs of three. The form was set on a sheet of building paper laid directly on the concrete floor. The form was filled before puddling. The top was leveled off with a trowel. After a period of one to two hours the tops of the blocks were finished by hand with a wood float. Instead of capping, the blocks were covered with a sheet of wet building paper and about 3 inches of damp sand. This method prevented loss of water while the blocks were in the forms.

All test pieces were allowed to remain in the metal forms over night. Upon removal of the forms they were stored in the manner indicated in Table 4. Two cylinders and five wear blocks were made in each group before the duplicate sets were begun. The duplicate sets were made two to four weeks after the first.

Methods of Testing.

The compression tests of concrete were made in a 200,000-pound Olsen universal testing machine. A spherical bearing block was used on top of the cylinders.

Wear tests of concrete were made in the Talbot-Jones rattler. The test pieces consist of blocks 8 inches square and 5 inches in thickness. The blocks are arranged around the perimeter of the drum of the rattler, as shown in Fig. 1. Ten blocks constitute a test set. The ten-side polygon formed by the test blocks presents at nearly continuous surface. The outside diameter of the polygon thus formed is 36 inches and the inside diameter 26 inches. During the test the front of the chamber is closed by means of a light steel plate. The abrasive charge consists of 200 pounds of cast-iron balls (about 133 1⅞ inches and 10 3¾ inches in diameter). These balls conform to the requirements for the standard rattler test of paving brick of the American Society for Testing Materials.

The test consists of exposing the inner faces of the concrete blocks to the wearing action of the charge for 1800 revolutions at the rate of 30 revolutions per minute. The machine was run for 900 revolutions in one direction, then reversed. Two sets of blocks are tested at once in the machine now in use. Each block was weighed upon removal from the form, upon removal from the damp sand, immediately before and after testing. The loss in weight during the test is used as a measure

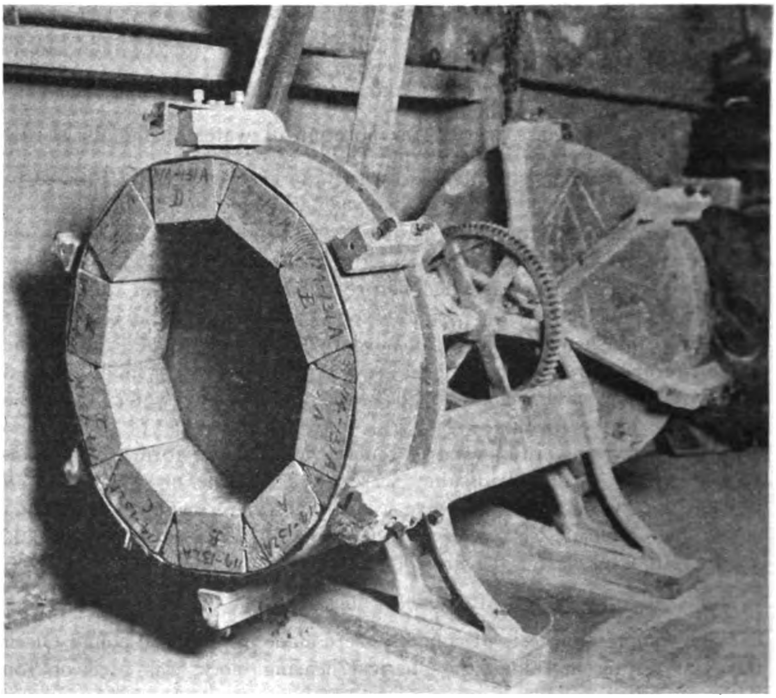


FIG. 1—TALBOT-JONES RATTLER WITH CONCRETE WEAR BLOCKS IN PLACE. Wear tests were made on blocks 8 inches square, 5 inches thick.

of the wear. This loss is reduced to an equivalent depth of wear in inches.

Absorption tests were made on two wear blocks from each set of 10. The tests were made when the blocks were about one year old, after having been stored in the open air in the laboratory during the period following the wear test. The blocks were dried to approximately constant weight on a steam radiator, weighed and immersed in water at room temperature. At various intervals they were removed from the water,

allowed to drain for about 5 minutes and weighed. The gain in weight was reduced to an equivalent volume of absorbed water.

DISCUSSION OF TESTS.

The tests included in this report consisted of compression tests of 120 6 x 12-inch concrete cylinders and 300 wear tests of 8 x 8 x 5-inch blocks, as well as miscellaneous tests of cement and aggregate. A 1-4 mix was used throughout, with aggregate graded up to 1¼ inches. In

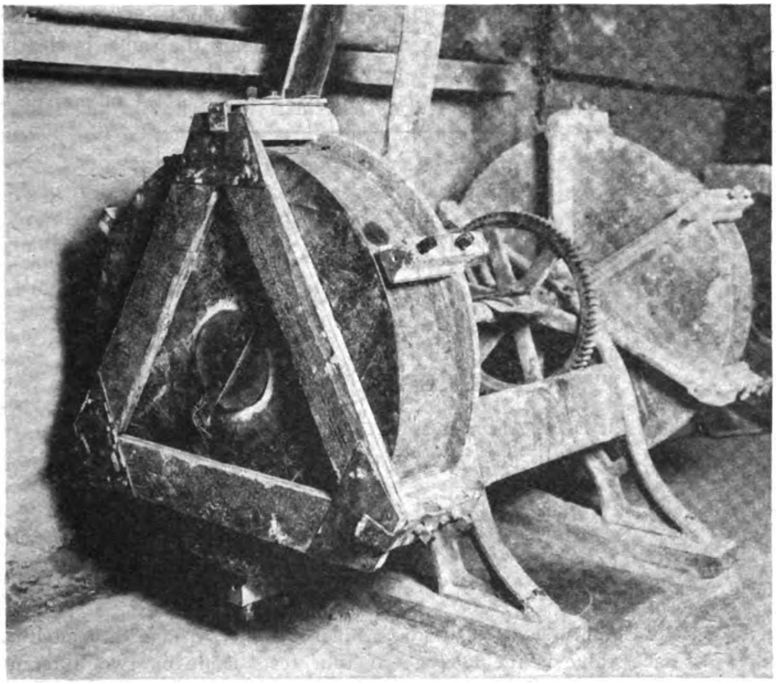


FIG. 2—TALBOT-JONES RATTLER WITH HEAD CLOSED READY FOR TEST.
The machine was operated for 1800 revolutions at 30 revolutions per minute. The abrasive charge consisted of 200 pounds of cast-iron balls.

general the coarse aggregate was pebbles; in one group of tests a crushed limestone was used. This mix is approximately the same as that generally used in one-course concrete road construction. Four different curing conditions were used for pebble aggregate as follows:

(1) Damp sand 4 months, tested damp.
(2) Damp sand 21 days, air 99 days.
(3) Damp sand 3 days, air 117 days.
(4) Air of laboratory for entire curing period of 4 months.

Group (1) was repeated, using crushed limestone as coarse aggregate. All compression and wear tests were made at age of 4 months. Average values from the strength and wear tests are given in Table 4.

EFFECT OF QUANTITY OF MIXING WATER ON THE STRENGTH OF CONCRETE.

Fig. 3 gives the results of the tests on the effect of quantity of mixing water on the compressive strength of concrete. A separate curve has been drawn for each curing condition. An average curve from these tests will be found in Fig. 8. The remarkable influence of the quantity of mixing water on the strength, other factors being the same, is clearly shown by these curves. It will be remembered that the consistency which we have called 1.00 (normal consistency) is such that a 1-4 mix gives a

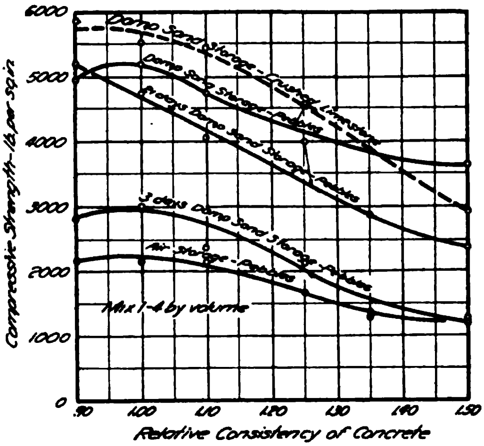


FIG. 3—EFFECT OF QUANTITY OF MIXING WATER ON THE STRENGTH OF CONCRETE.

Compression tests of 6 x 12-inch cylinders at age of 4 months. Each value is the average of four tests made on two different days. Same data as in Fig. 5.

slump of ½ to 1 inch when the form is slipped off the freshly molded cylinder. A consistency of .90 contains 90 per cent. of the amount of water required for normal consistency; a consistency of 1.50 contains 1½ times the quantity of water used in the normal consistency concrete, etc. The normal consistency concrete may be characterized as plastic; the .90 is somewhat dry; the 1.50 quite wet, but contains much less water than the "sloppy" mixes frequently seen in reinforced concrete work.

It will be noted that there is a rapid falling-off in strength as the water content is increased from normal consistency. With a consistency of 1.25 the strength is reduced to about 75 per cent. of the highest; with a consistency of 1.50 the strength is only one-half that which may be

obtained with the same cement content. For wetter mixes the strength would be still further reduced.

In general it will not be feasible to use concrete of a consistency which will give maximum strength, since it is somewhat too stiff for satisfactory workability. In concrete road work where hand finishing is used the concrete must be mixed to a consistency varying from 1.10 to 1.15. In other words, we must sacrifice a portion of the possible strength of the concrete in order to secure a workable mix. This consistency will give a slump of 5 to 7 inches. If machine finishing is employed the concrete can be mixed to a consistency corresponding closely to maximum strength. In reinforced concrete work there is in general little excuse for using mixes wetter than 1.25 consistency, corresponding to a slump of 8 to 9 inches.

The average curves in Fig. 8 have been platted in terms of the water-ratio instead of the relative consistencies, although relative consistencies are also shown. The water-ratio is the ratio by volume of water to cement in the batch.

Further Discussion of Effect of Quantity of Mixing Water on the Strength of Concrete.

Many series of tests made in this laboratory have fully established the fundamental importance of the quantity of mixing water on the strength of concrete.

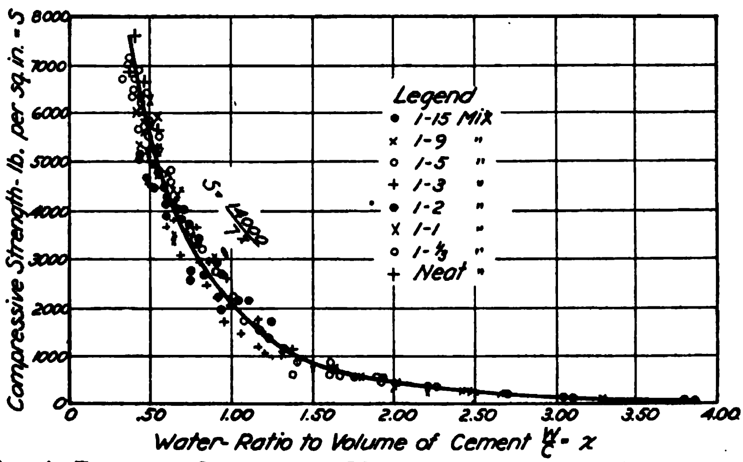


Fig. 4—Effect of Quantity of Mixing Water on the Strength of Concrete.

Compression tests of 6 x 12-inch cylinders at age of 28 days. Each value is the average from five tests. Details of tests not given in this report.

Fig. 4 gives the average values from a series of tests of this kind in which the compressive strength is platted against the water-ratio of

the concrete. In this series the mixes ranged from 1-15 up to neat cement. The consistencies were varied over a wide range. The size of the aggregate ranged from a very fine sand to a coarse concrete aggregate, for all combinations of mix and consistency. Further details of these tests are not given in this report.

In the figure distinguishing marks were used for each mix, but no distinction was made between aggregates of different sizes or concretes of different consistencies. When the compressive strength is platted against the water content in this way a smooth curve is obtained due to the overlapping of the points for different mixes, consistencies, etc. Values from the dry concretes have been omitted from the diagram; if these were used we should obtain a series of curves dropping downward to the left from the curve shown. It is seen at once that the size and grading of the aggregate and the quantity of cement are no longer of any importance except in so far as these factors influence the quantity of mixing water required to produce a workable concrete. This gives an entirely new conception of the function of the constituent materials entering into a concrete mixture.

The equation of the curve in Fig. 4 is of the form

$$S = \frac{A}{B^x}$$

where S is the compressive strength of the concrete and x is the ratio of the volume of water to volume of cement in the batch (water-ratio). A and B are constants whose values depend on the quality of the cement used and on other conditions of the test.

The values of the constants in these tests are shown on the diagram. This equation expresses the law of the strength of concrete so far as variations in the proportions of materials are concerned. It is seen that for given concrete materials the strength depends on only one factor—the water-ratio. Equations which have been proposed for this purpose in the past contain terms which take into account such factors as quantity of cement, proportions of fine and coarse aggregate, voids in aggregate, etc., but they have uniformly omitted the only item which is of any importance; that is, the water. The relation given above holds so long as the concrete is not too dry for maximum strength, and the aggregate not too coarse for a given quantity of cement; in other words, so long as we have a workable concrete.

The strength of the concrete responds to changes in water, regardless of the reason for these changes. The water-ratio may be changed due to any of the following causes:

(1) Change in mix (cement content).
(2) Change in size or grading of aggregate.
(3) Change in relative consistency.
(4) Any combination of (1) to (3).

In certain instances a 1-9 mix is as strong as a 1-2 mix, depending only on water content. It should not be concluded that these tests indi-

cate that lean mixes can be substituted for richer ones without limit. We are always limited by the necessity of using sufficient water to secure a workable mix. So in the case of the grading of aggregates. The workability of the mix will in all cases dictate the minimum quantity of water that can be used. The importance of the workability factor in concrete is therefore brought out in its true relation.

The problem of designing concrete mixes resolves itself into this: To produce a workable concrete with a given water-ratio using a minimum of cement; or the converse, to produce a workable concrete which has the lowest water-ratio for a given quantity of cement. The methods of securing the best grading of aggregate and the use of the driest practicable concrete are seen to be only devices for accomplishing the above-mentioned results. A forthcoming Bulletin on the "Design of Concrete Mixtures" will give further details of the principles underlying the proportioning of concrete, and discuss their application to practical problems.

The influence of the water-ratio of concrete on its strength will be shown by the following considerations: One pint more water than necessary to produce a plastic concrete in a 1-4 mix reduces the strength to

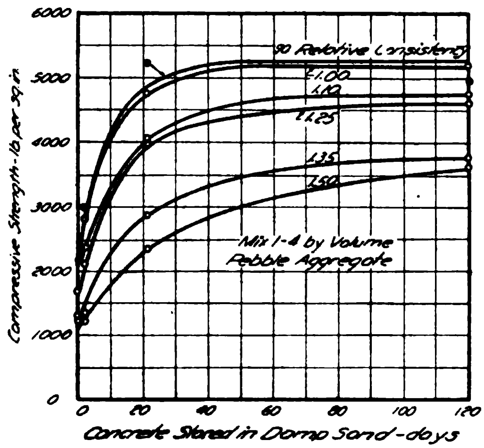


FIG. 5—EFFECT OF CURING CONDITIONS ON THE COMPRESSIVE STRENGTH OF CONCRETE.

Compression tests of 6 x 12-inch cylinders at age of 4 months. Each value is the average of four tests made on two different days. Same data as in Fig. 4.

the same extent as if we should omit 2 to 3 pounds of cement from a one-bag batch.

Our studies give us an entirely new conception of the function performed by the various constituent materials. The use of a coarse, well-graded aggregate results in no gain in strength unless we take advantage

of the fact that the amount of water necessary to produce a plastic mix can thus be reduced. In a similar way we may say that the use of more cement in a batch does not produce any beneficial effect, except from the fact that a plastic, workable mix can be produced with relatively less water.

The reason a rich mixture gives a higher strength than a lean one is not that more cement is used, but because the concrete can be mixed (and usually is mixed) with a lower water-ratio in the case of the richer mixtures than for the lean ones. If advantage is not taken of the fact that in a rich mix relatively less water can be used, no benefit will be gained as compared with a leaner mix. In all this discussion the quantity of water is compared with the quantity of cement in the batch (cubic feet of water to one sack of cement) and not to the weight of dry materials or of the concrete, as is generally done.

For the other curves showing the strength water-ratio relation, see paper on "Time of Mixing Concrete," referred to above.

Effect of Quantity of Mixing Water on the Wear of Concrete.

Figs. 6 and 8 give the results of tests to determine the effect of quantity of mixing water on the wear of concrete. It will be noted that

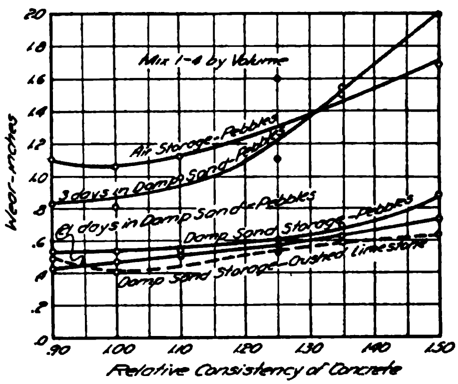


Fig. 6—Effect of Quantity of Mixing Water on the Wear of Concrete.

Wear tests of 8 x 8 x 5-inch blocks at age of 4 months. Each value is the average of 10 blocks made on two different days. Same data as in Fig. 7.

the depth of wear is expressed in inches. The wear-water-ratio relation is just opposite to that found in the strength tests; in other words, a high strength is accompanied by low wear, and vice versa. If the wear curve in Fig. 8 were inverted we should have almost a duplicate of the strength curve. In general, the lowest wear is found at about the same

water-ratio as the highest strength. The average curves (Fig. 8) show that maximum strength and minimum wear come at a consistency of about .95, or a water-ratio of about .70. It should be pointed out that for other mixes the best results would probably be found at about the same relative consistency, but at a different water-ratio. For a given consistency the water-ratio is higher for lean mixes and lower for rich mixes.

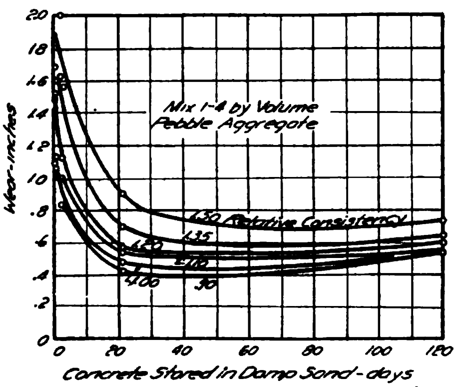


FIG. 7—EFFECT OF CURING CONDITIONS ON THE WEAR OF CONCRETE.
Wear tests of 8 x 8 x 5-inch blocks at age of 4 months. Each value is the average of 10 blocks made on two different days. Same data as in Fig. 6.

WATER REQUIRED FOR CONCRETE MIXES.

Since the quantity of mixing water exerts such an important influence on the strength and other properties of concrete, it will be of interest to examine the factors which influence the amount of water required for satisfactory results. The function of water in concrete is twofold:

(1) To supply the water necessary for hydration of the cement.

(2) To produce a plastic mixture.

While the exact quantity of water required under (1) has not been determined except in certain instances, it is generally agreed that the quantity used in concrete is greatly in excess of that necessary for hydration of the cement. The bulk of the water in concrete is used in order to produce a plastic or workable mix. The exact quantity required for this purpose depends on the materials used, nature of the work, and methods of handling and finishing.

It is, in general, impracticable to state in definite quantities the amount of water which should be used, since this depends on many different factors, such as the following:

(1) The relative consistency which must be used, which is dictated by the nature of the work.
(2) The normal consistency of the cement.
(3) The quantity of cement.
(4) The size and grading of the aggregate.
(5) The absorption of the aggregate.
(6) The moisture content of the aggregate.
(7) Admixtures which may be used.

A water formula has been developed which takes into account all these elements; however, since it involves certain factors which cannot be covered in this report, a discussion of this phase of the work will be deferred.

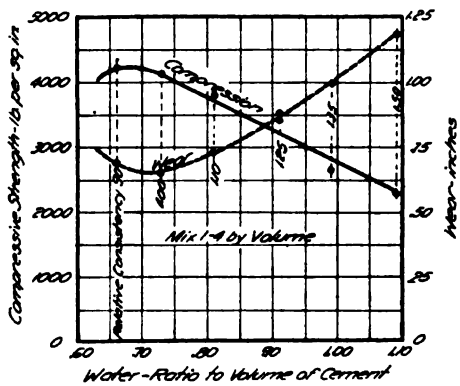


Fig. 8—Effect of Quantity of Mixing Water on the Strength and Wear of Concrete.

Average curves from Figs. 4 and 6. The quantity of mixing water is expressed as a ratio to the volume of cement in the batch. Each value for compression is the average of 20 tests (four curing conditions). Each value for wear is the average of 50 tests (four curing conditions). In interpreting this diagram it should be borne in mind that we have averaged the four storage conditions described in Table 4. For best curing conditions concrete will show much less wear than any indicated by this curve.

The quantity of water which affects the water-ratio as given in Fig. 8 is only such a part of the whole as affects the cement. In other words, the water which is absorbed by the aggregate is not considered as influencing the water-ratio. This makes it plain that the absorption of the aggregate must be taken into account if concretes from widely different aggregates are being compared. Many serious errors have been made

in drawing conclusions from tests, due to failure to take into account the influence of absorption, grading of aggregates, etc., on the water content of the concrete.

In general, it is impracticable to determine in advance the exact quantity of water required for concrete mixes, largely due to two causes: (1) Inability to determine in advance the lowest relative consistency which may be used and still produce a workable concrete; (2) varying moisture content of aggregates.

The following table may be of interest in indicating the approximate quantities of water necessary for certain mixes. It is assumed that a well-graded aggregate up to 1½ inches in size will be used. Only under the most favorable conditions can the minimum values be used; in general, the maximum values need not be exceeded.

Mix		Approximate Mix as Usually Expressed			Water Required (Gallons per Sack of Cement)	
Cement	Volume of Aggregate After Mixing	Cement	Aggregate		Minimum	Maximum
			Fine	Coarse		
1	5	1	2	4	6	6½
1	4½	1	2	3	5¾	6¼
1	4	1	1½	3	5½	6
1	3	1	1¼	2½	5	5½

Without regard to the actual quantity of mixing water, the following rule is a safe one to follow:

> "Use the *smallest quantity* of mixing water that will produce a workable mix."

The importance of methods of proportioning, mixing, handling, placing or finishing concrete which will enable the builder to reduce the water content to a minimum is at once apparent.

Effect of Curing Condition on the Strength of Concrete.

The effect of curing condition on the compressive strength of concrete is shown in Fig. 5; an average curve is given in Fig. 9. All consistencies of concrete show great increases in strength under favorable curing conditions as compared with specimens which were allowed to dry out at once. The dryer mixes show a more rapid improvement due to storage in a damp place during the first few days than the wetter ones. Even 3 days in damp sand shows an increase in strength of the dryer concretes of about 35 per cent. as compared with the specimens stored in open air for the entire period. It should be borne in mind that in the most unfavorable case used in the experiments the concrete was in the steel form for 1 day with only the top exposed, consequently the conditions were more favorable than those frequently found in summer weather or in arid regions where the concrete is exposed to rapid evaporation of the mixing water from the moment it is placed.

The concrete stored for 4 months in damp sand and tested damp is 2½ to 3 times as strong as similar concrete which has been exposed to room atmosphere for the same period. Protecting the concrete from drying out for only 10 days (taking values from Figs. 5 and 9) gives an increase in strength of about 75 per cent. for the dryer mixes.

Effect of Curing Condition on the Wear of Concrete.

The effect of curing condition on the wear of concrete is no less striking than the effect on the strength.

It will be seen in Fig. 7 that the blocks stored for the entire period of 4 months in damp sand showed more wear in most instances than those

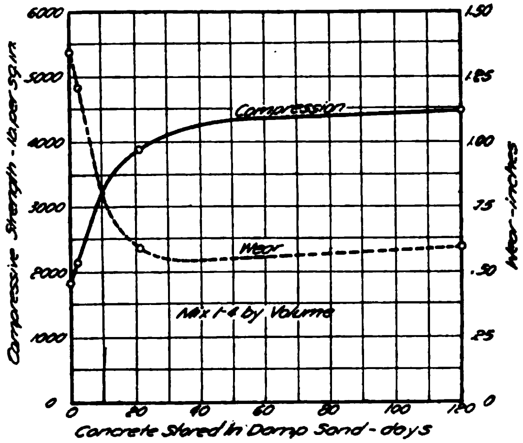


Fig. 9—Effect of Curing Condition on the Strength and Wear of Concrete.

Average curves from Figs. 5 and 7. Each value for compression is the average of 24 tests (four each for six consistencies). Each value for wear is the average of 60 blocks (10 each for six consistencies). The upward trend of the wear curve results from the abnormal wear of the 4-month sand-stored blocks on account of being tested in damp condition.

which had been stored for 21 days in damp sand and the remainder of the time in air. This peculiar result is no doubt due to the fact that the concrete was tested in a damp condition, and does not indicate that the longer period in damp sand is injurious. The comparison would have been more nearly correct if the blocks had been allowed to dry out a few days before testing. These results do show that concrete in a wet or damp condition suffers more from wear than when dry. It is a matter of common experience that non-metallic materials, such as timber, terra cotta, concrete, stone, etc., which absorb water, show a lower strength

in a wet condition than when dry. Additional tests will be required to show the exact effect of moisture content on strength and wear of concrete, other factors being the same.

It is not necessary to speculate on the probable effect of moisture in the concrete in order to secure valuable information from these tests. The dryer mixes show an increase in wear from .50 inch for concrete stored in damp sand for 21 days, to 1.10 inches for concrete in air for entire period; the tests indicate that 10 days in damp storage would give a wear of about .65 inch. For the wetter mixes the wear after 21 days in damp sand is about .85 inch; for 10 days 1.15 inches; for air storage throughout probably 2 inches. In the wetter consistencies the tests were not carried to completion on account of disintegration of certain blocks, which caused the entire ring to collapse.

The photographs in Figs. 15 to 20 show side views of the blocks after test. The effect of both consistency and curing condition are clearly shown by the relative thickness of the blocks.

Recapitulation of Effect of Consistency and Curing Condition.

In view of the important influence of consistency and curing conditions of concrete shown by these tests, it seems doubtful if there is any phase of concrete work which will pay such high dividends as a little care to see that proper consistency is used and desirable curing conditions are provided. In many instances the quality of the concrete could be vastly improved at trifling expense, but nothing is done because those in charge do not appreciate the importance of care in these directions. The writer is convinced that practically all of the faults from concrete floors follow from these two causes. Excessive wear and dusting are certain to result in a floor in which the concrete is never allowed to have the water necessary for hydration of the cement. It is notable that dusting never occurs on a concrete road, for the reason that it gradually gets the water necessary for hydration from rain or snow. However, due to low wearing resistance at early periods, resulting from premature drying, it may be badly worn before rain comes.

An excess of mixing water is a serious fault in concrete. If, in addition to too much water the concrete is allowed to dry out at once it is almost certain to be a failure if subjected to wear and will give very low strength. For the two wettest consistencies and the two most unfavorable curing conditions, the compressive strength of the pebble concrete was 1300 pounds per square inch; for the two most favorable curing conditions and the three dryest consistencies the average compressive strength was 4850 pounds per square inch—an increase of 275 per cent. In the case of the wear tests the corresponding values are 1.70 inches and .50 inch; an increase of 240 per cent. The comparison in the wear test is not as unfavorable as it should have been, since the poorer blocks broke up before the test was completed.

Proper curing of concrete is second only in importance to the control of water content. The rule stated above with reference to water content may now be extended to the following:

> Use the *smallest quantity* of mixing water that will produce a workable concrete, then allow the concrete to have *as much water as possible* during the period of curing.

All concrete should be protected against premature drying for at least one week, and longer if practicable. This period should be extended to 10 days or two weeks in cool weather, or where the concrete is to be subjected to heavy traffic at an early age.

Covering with damp sand or earth, or wet burlap are excellent methods of curing. The practice of "ponding" is common in road construction. The writer wishes to offer a word of caution with reference to the use of wet sawdust for covering concrete floors. Sawdust may have most harmful results, on account of the organic acids present.

Compression tests of concrete made in other series show that the strength of concrete increases indefinitely, so long as it is not permitted to dry out.*

Relation Between Strength and Wear of Concrete.

The relation between strength and wear of concrete in this series is shown in Fig. 10. All tests have been platted. Each value is based on the average of four compression tests and 10 wear tests. This diagram shows that a definite relation exists between strength and wear at least for the conditions of these tests; that is, for concrete of different consistencies and curing conditions. Further tests will be necessary to show whether or not this relation is entirely general for other aggregates, etc.

Fig. 11 is the same curve platted to log. scale. The straight line in this diagram enables us to devise the equation:

$$S = \frac{2230}{W^{1.07}}$$

as showing the relation between the variables; where S = compressive strength in pounds per square inch and W = the depth of wear in inches.

A similar relation from another series of strength and wear tests made in this laboratory will be found in Figs. 14 and 15 of the paper on "Effect of Time of Mixing," referred to above.

Comparison of Pebble and Crushed Stone Aggregate.

Crushed limestone was used as coarse aggregate in one group of tests. In general the limestone concrete gave somewhat higher strength and lower wear than the gravel concrete using the same sand and the same water and cement. However, the tests do not cover a sufficient

*See "Effect of Age on the Strength of Concrete," by D. A. Abrams, Proc. American Society for Testing Materials, Part II, 1918.

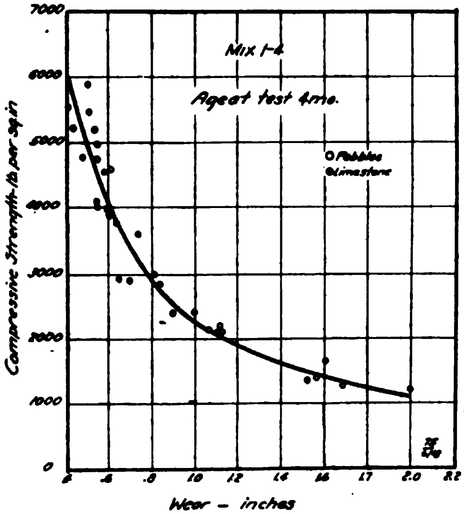


FIG. 10—RELATION BETWEEN THE COMPRESSIVE STRENGTH AND WEAR OF CONCRETE.

Compression tests of 6 x 12-inch cylinders, and wear tests of 8 x 8 x 5-inch blocks at age of 4 months. Each value is based on the averages of four compression tests and 10 wear tests. All consistencies and curing conditions are included.

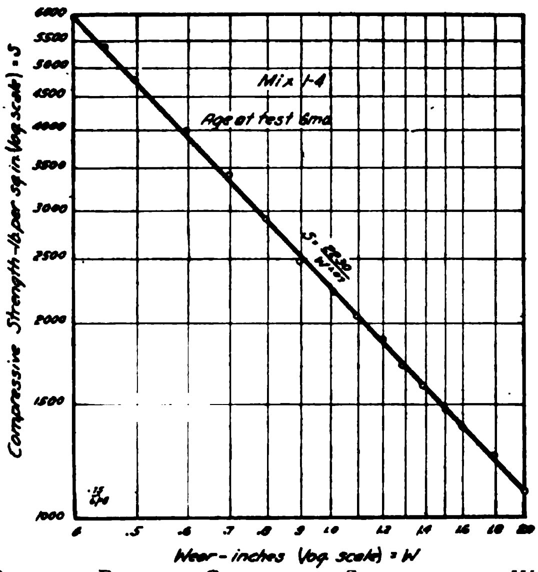


FIG. 11—RELATION BETWEEN COMPRESSIVE STRENGTH AND WEAR OF CONCRETE.

Same data as in Fig. 10, except curve platted on logarithmic scales. The points shown are taken from the curve in Fig. 10.

range to justify definite comparisons of the merits of the two types of aggregate. Both of the aggregates used in this series were of high grade and gave good results in the tests. Other tests now under way and planned for the future are expected to give definite information on the relative merits of different aggregates.

Method of Making Wear Tests.

The Talbot-Jones rattler has been found entirely successful as a method of studying the wear of concrete in the laboratory. The results

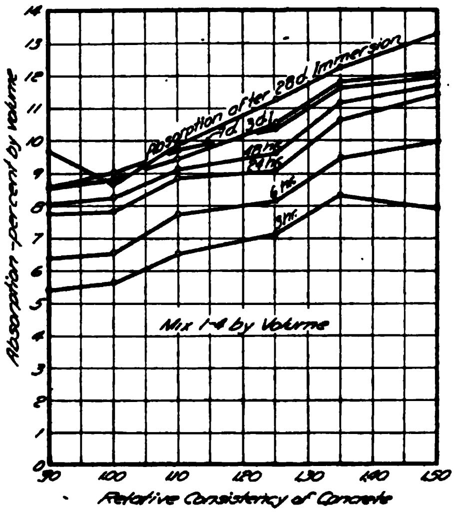


Fig. 12—Effect of Quantity of Mixing Water on the Absorption of Concrete.

Absorption tests of 8 x 8 x 5-inch blocks. Pebble aggregate. Age 1 year. Absorption determined after immersion in water at room temperature. Each value is the average of eight blocks from four different curing conditions—one block from each set of pebble aggregates in Table 5. Absorption is given by volumes; absorption by weight is about 40 per cent. of these values.

of the tests thus far completed and the definite relations found between the wear and strength have given considerable confidence to this method of testing. The abrasive charge of 200 pounds of cast-iron balls, and the rate and number of revolutions used, gives a wearing action suited for a wide range in the properties of concrete. A very poor concrete may be entirely destroyed, a high-grade concrete will show a wear of ½ inch or less.

The test gives a combination of abrasion and impact that cannot be withstood by an inferior concrete. The severity of the impact may be

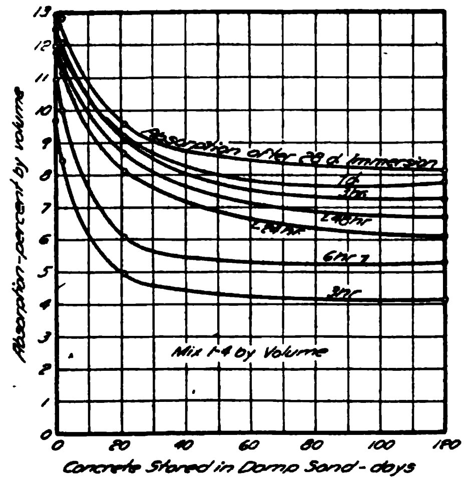


FIG. 13—EFFECT OF CURING CONDITIONS ON THE ABSORPTION OF CONCRETE. Absorption tests of 8 x 8 x 5-inch blocks. Absorption determined after immersion in water at room temperature. Each value is the average of 12 blocks from six different consistencies. Same data as in Fig. 12. Absorption is given by volumes; absorption by weight is about 40 per cent. of these values.

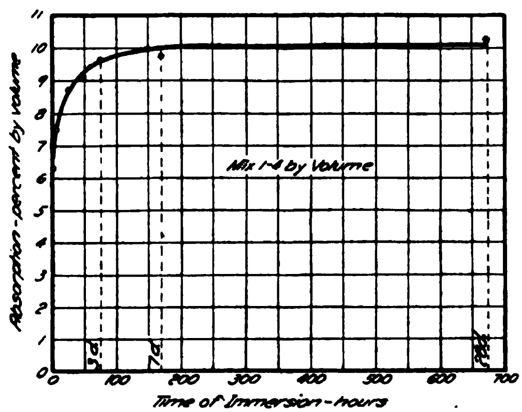


FIG. 14—EFFECT OF TIME OF IMMERSION ON THE ABSORPTION OF CONCRETE. Absorption tests of 8 x 8 x 5-inch blocks. Absorption determined after immersion in water at room temperature. Each value is the average of 48 tests from six consistencies and four curing conditions. Data from Table 5. Absorption is given by volumes; absorption by weight is about 40 per cent. of these values.

seen from the fact that the 1⅞-inch cast-iron balls are frequently broken during the test. While the test does not fully duplicate the action of traffic, it furnishes a valuable guide to the relative effects of different methods of treatment, materials, etc., for use in pavement construction.

This method of making wear tests of concrete is believed to have the following advantages as compared with other methods which have been used or proposed for this purpose:

(1) The concrete is subjected to a treatment which approximates that of service.

(2) The test piece is of usual form and of sufficient size that representative concrete can be obtained.

(3) The test pieces are convenient to make, store and handle, and require a relatively small quantity of concrete.

(4) The cost of tests is not excessive.

(5) The machine used is found in a number of testing laboratories.

(6) The wearing action takes place on the top or finished surface of the concrete. This makes it possible to study the effect of various surface treatments and finishes.

(7) Several tests may be made at the same time, thus enabling more representative results to be obtained.

(8) Tests may be made on sections of concrete cut from roads which have been in service.

(9) Other paving materials, such as brick, granite blocks, etc., may be tested in the same manner as the concrete.

Absorption Tests of Concrete.

Absorption was determined on two wear blocks from each set of 10, after immersion in water for periods of 3 hours to 28 days. It should be noted that absorption tests were made on blocks at the age of 1 year, which had been tested for wear at 4 months.

The results of absorption tests are given in Table 5, and in Figs. 13 and 14. In Fig. 13 all consistencies for a given curing condition have been averaged. It is interesting to note that the absorption is influenced by the curing condition of the concrete in the same way as the wear. (Compare Figs. 13 and 7.) The curing condition that gives high wear, gives high absorption, and vice-versa.

The effect of consistency and curing condition on absorption is shown by an average absorption of 5.77 per cent. for the most favorable conditions after 24-hour immersion and 12.6 per cent. for the most unfavorable conditions. The absorption is here given by volumes; the absorption by weight would be only about 40 per cent. of these values.

The effect of time of immersion on the absorption is shown in Fig. 14; all consistencies and curing conditions have been averaged for a given time of immersion.

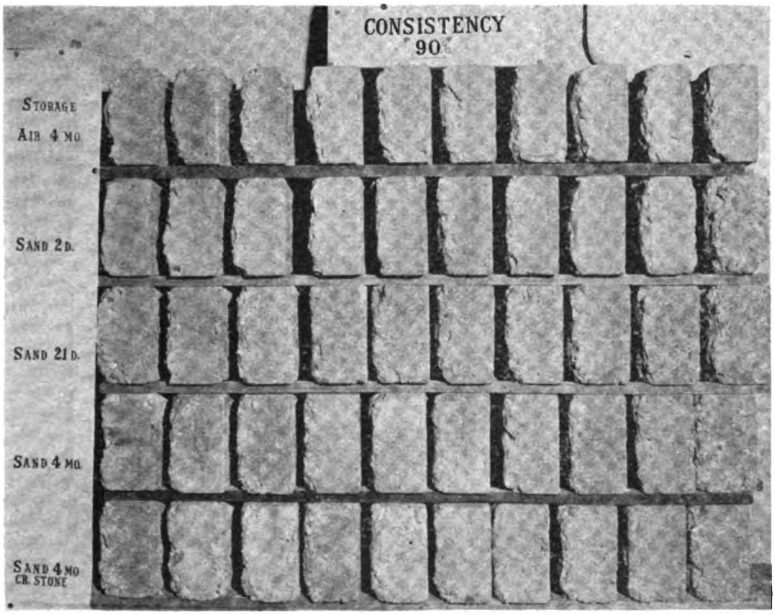


FIG. 15—SIDE VIEW OF WEAR BLOCKS AFTER TEST.
The effect of storage condition on wear is clearly shown.

Storage Air 4 mo.

Sand 2 d.

Sand 21 d.

Sand 4 mo.

Sand 4 mo. Cr. Stone

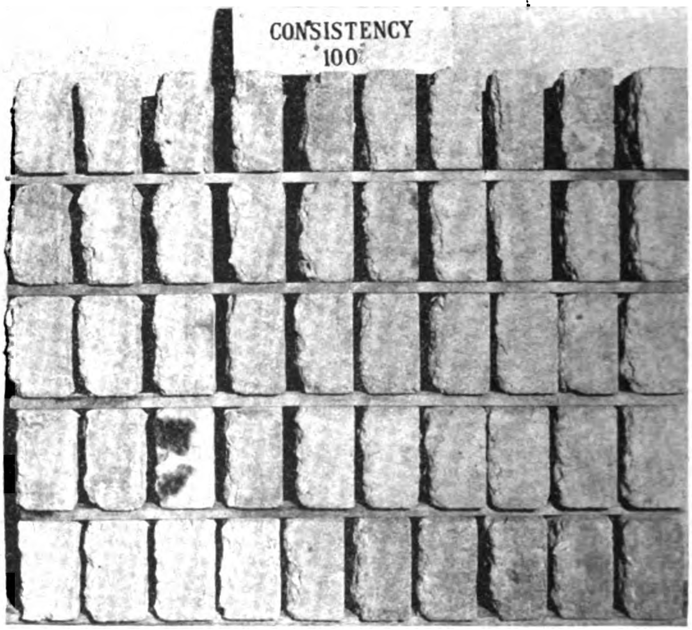


Fig. 16—Side View of Wear Blocks after Test.
The effect of storage condition on wear is clearly shown.

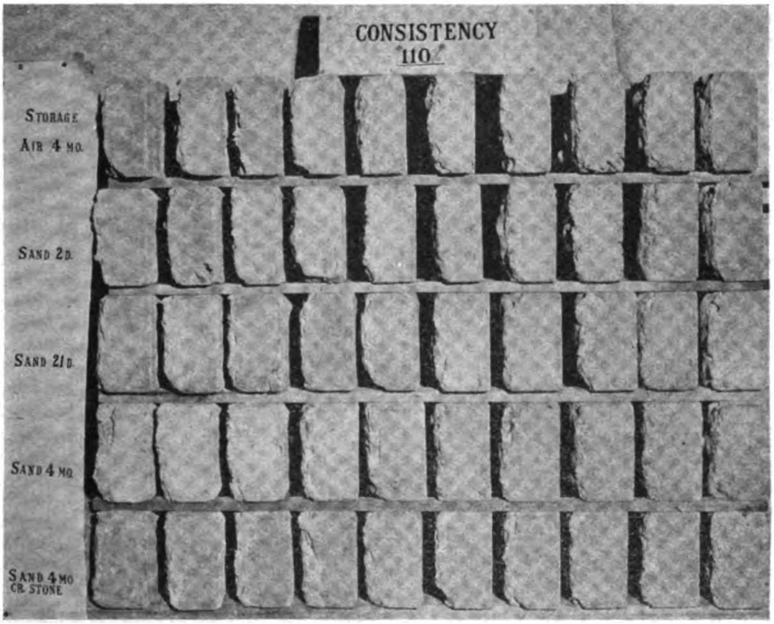


FIG. 17—SIDE VIEW OF WEAR BLOCKS AFTER TEST.
The effect of storage condition on wear is clearly shown.

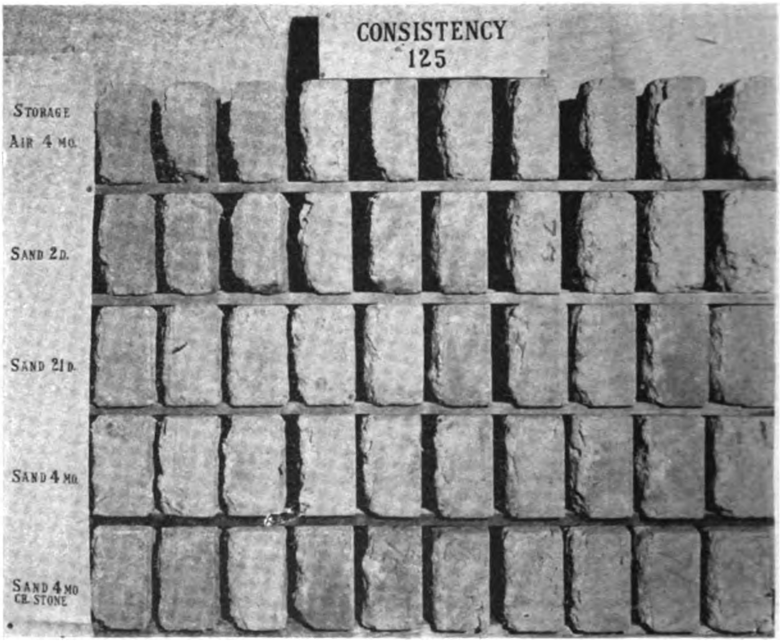


FIG. 18—SIDE VIEW OF WEAR BLOCKS AFTER TEST.
The effect of storage condition on wear is clearly shown.

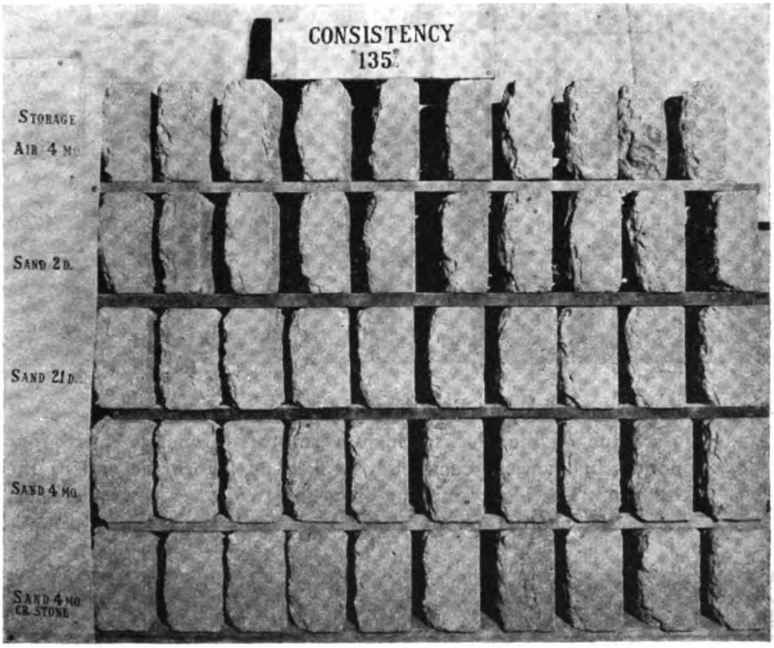


FIG. 19—SIDE VIEW OF WEAR BLOCKS AFTER TEST.
The effect of storage condition on wear is clearly shown.

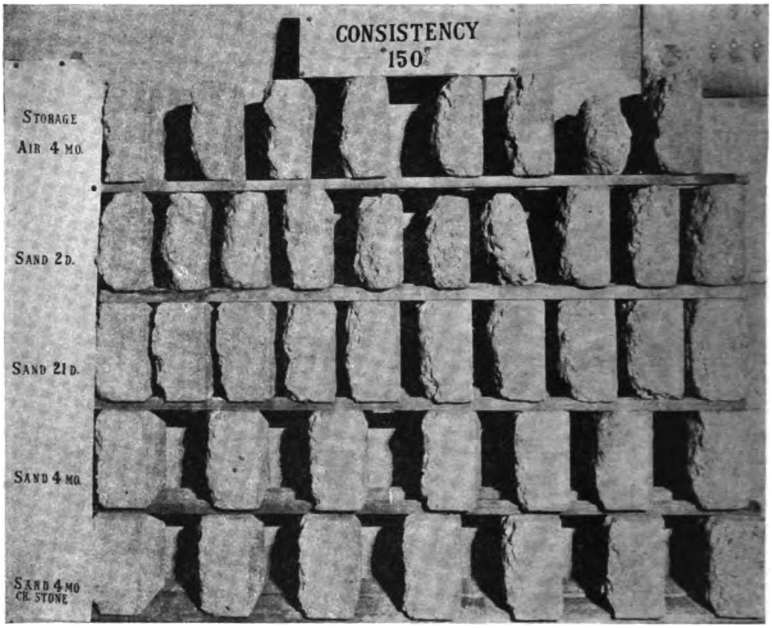


FIG. 20—SIDE VIEW OF WEAR BLOCKS AFTER TEST.

Some of the blocks which were stored for the entire four months in air were completely broken up before the end of the test run. The blocks missing from the two lower rows were lost before the photograph was taken.

FIG. 21—FRONT VIEW OF WEAR BLOCKS AFTER TEST.

Top row, gravel as coarse aggregate.
Bottom row, crushed limestone as coarse aggregate.

Unit Weight of Concrete.

The unit weight of all test pieces was determined immediately before test at the age of 4 months. The values are given in Table 6. Each value is the average from four cylinders and 10 wear blocks. The weight of the concrete is little affected by the consistency, but is greatly influenced by the curing condition. The weights of the specimens stored for 4 months in damp sand cannot be compared directly with the others, since they contained free moisture; that is, water in the uncombined state. A comparison of the average weights of all consistencies for the other curing conditions shows that the concrete stored 3 days in damp sand took up .33 pound more water and that stored for 21 days in damp sand 2.16 pounds more water per cubic foot than that stored in air throughout the 4 months. Since all test pieces were in the same room-dry condition when the weights were determined, it seems that these values may be taken as approximate measures of the additional quantities of water which have entered into chemical combination with the cement, due to storage in a damp place for these periods.

Table 1—Tests of Cement.

The cement consisted of a mixture of equal parts of four brands purchased on the Chicago market (Lot No. 3705).

All tests made in accordance with standard methods of the American Society for Testing Materials.

Miscellaneous Tests.

Fineness Residue on 200 Sieve	Normal Consistency Per Cent by Weight	Time of Setting				Soundness Test (over Boiling Water)
		Vicat Needle		Gillmore Needle		
		Initial	Final	Initial	Final	
		h. m.	h. m.	h. m.	h. m.	
20.4	23.0	4.25	8 05	5.10	8.45	O.K.

Mortar Strength Tests.

1-3 standard sand mortar.

Mixing Water Percent	Briquets Tensile Strength — lb. per sq. in.						2 by 4-in. Cylinders Compressive Strength — lb. per sq. in.					
	7 Da.	28 Da.	3 Mo.	6 Mo.	1 Yr.	2 Yr.	7 Da.	28 Da.	3 Mo.	6 Mo.	1 Yr.	2 Yr.
10.3	266	367	464	431	415	357	2080	3800	4240	5130	5060	4600

TABLE 2—SIEVE ANALYSIS OF AGGREGATES.

Sieves manufactured by the W. S. Tyler Company, Cleveland, Ohio.

Sieve Number or Size	Size of Clear Opening inches	Per Cent. by Weight Coarser than Each Sieve				
		Sand	Pebbles	Crushed Limestone	Sand and Pebbles	Sand and Limestone
100	.0058	98	100	100	99	99
48	.0116	90	100	100	96	96
28	.023	60	100	100	84	84
14	.046	42	100	100	77	77
8	.093	22	100	100	69	69
4	.185	0	100	100	60	60
⅜	.37	....	84	84	50	50
¾	.75	....	50	50	30	30
1¼	1.25	....	0	0	0	0

TABLE 3—MISCELLANEOUS TESTS OF AGGREGATES.

Test	Sand	Pebbles	Crushed Limestone	Sand and Pebbles	Sand and Limestone
Unit Weight of Dry Aggregate lb. per cu. ft.	115.5	112.5	99.5	131.0	123.0
Absorption of Aggregate †					
Per cent. by volume	2.3	2.2	1.6	....	....
Per cent. by weight	1.3	1.3	1.0	....	....
Abrasion Test ‡ Loss in weight—per cent.					
Standard method	....	2.3	5.2	....	....
Rea's method	....	8.8	12.3	....	....

†After immersion in water at room temperature for 8 hrs.

‡Abrasion tests were made in the Deval abrasion testing machine. In the Standard method a sample of 50 pieces weighing 5000 g. was placed in the test chamber and run for 10,000 revolutions. Rea's method was first used by A. S. Rea, of the Ohio State Highway Department, Columbus. It consists in using a 5000-g. sample, made up of 2500 g. of aggregate ¼ to ¾ in. in size and 2500 g. of aggregate ¾ to 1¼ in. In addition to the aggregate six 1⅞ in. cast-iron balls were placed in the test chamber as an abrasive charge. The entire sample was run for 10,000 revolutions. It will be seen that Rea's method is much more severe than the Standard method.

TABLE 4—WEAR AND COMPRESSION TESTS OF CONCRETE.

Hand-mixed concrete. Mixed 1-4 by volume. Age atest, 4 months.
Aggregate graded 0-1¼ in.
The same sand used in all tests.
Coarse aggregate consisted of pebbles or crushed limestone of the same grading.
The specimens were stored for the period shown in damp sand, the remainder of the time in the air of the Laboratory.
Wear tests made in Talbot-Jones rattler—total of 1800 revolutions.
Wear tests are average of five 8 by 8 by 5-in. blocks.
Compression tests are average of two 6 by 12-in. cylinders.
The second set of tests in each group was made 2 to 4 weeks after the first.

Coarse Aggregate	Mixing Water		Depth of Wear—Inches 8 by 8 by 5-Inch Blocks				Compressive Strength—Lbs. Per Sq. In. 6 by 12-Inch Cylinders			
	Relative Consistency	Water Ratio	Damp Sand Storage	21 Days in Damp Sand	3 Days in Damp Sand	Air Storage	Damp Sand Storage	21 Days in Damp Sand	3 Days in Damp Sand	Air Storage
Pebbles....................	.90	.66	.53 .54 .54	.34 .51 .43	.82 .84 .83	1.29 .91 1.10	4970 4990 4980	5310 5150 5230	2890 2720 2810	2110 2260 2190
Crushed Limestone.........	.90	.66	.48 .52 .50	....	....	....	5970 5700 5890	....	....	....
Pebbles....................	1.00	.73	.54 .52 .53	.52 .41 .47	.83 .78 .81	1.01 1.10 1.06	5530 4760 5200	4550 4960 4760	3040 2960 3000	2290 2020 2160
Crushed Limestone.........	1.00	.73	.34 .46 .40	....	....	....	5800 5280 5540	....	....	....
Pebbles....................	1.10	.81	.52 .56 .54	.51 .54 .53	1.00 .98 .99	1.23 1.02 1.12	4470 5020 4750	3940 4220 4080	2350 2410 2380	2240 2050 2150
Crushed Limestone.........	1.10	.81	.48 .52 .50	....	....	....	5390 5540 5470	....	....	....
Pebbles....................	1.25	.91	.57 .63 .60	.51 .56 .54	.96 1.25 1.10	1.56 1.64 1.60	4700 4490 4600	4350 3640 4000	2360 1900 2130	1640 1710 1680
Crushed Limestone.........	1.25	.91	.58 .56 .57	....	....	....	4320 4850 4590	....	....	....
Pebbles....................	1.35	.99	.59 .66 .63	.69 .69 .69	1.49 1.61 1.55	2.40 1.51* 1.51 1.51*	3860 3650 3760	2570 3190 2880	1400 1310 1360	1420 1250 1340
Crushed Limestone.........	1.35	.99	.59 .61 .60	....	....	....	3910 3820 3870	....	....	....
Pebbles....................	1.50	1.09	.74 .73 .73	.85 .92 .89	2.34 2.00* ....† 2.00*	1.68 ....† 1.68	3740 3530 3640	2300 2440 2370	1330 1090 1210	1280 1240 1260
Crushed Limestone.........	1.50	1.09	.60 .68 .64	....	....	....	2640 3190 2920	....	....	....

*Omitting one badly damaged block.
†One block disintegrated, allowing entire charge to fall out after about 1100 revolutions.

Table 5—Absorption Tests of Concrete.

Hand-mixed concrete.
Mix 1-4 by volume.
Aggregate graded 0-1¼ in.

The same sand used in all tests—torpedo sand from Elgin, Ill.

Coarse aggregate consisted of pebbles or crushed limestone of same grading.

Age at test 1 year. The tests were made on 8 by 8 by 5-in. concrete blocks which had previously been used in wear tests at the age of 4 months. Immediately after molding the blocks were stored for the period shown in damp sand, the remainder of the time in the air in the Laboratory.

During the absorption test the blocks were immersed in water at room temperature.

Each value is the average of 2 blocks made on different days.

Coarse Aggregate	Mixing Water		Absorption—Per Cent. by Volume											
	Relative Consistency	Water Ratio	Damp Sand Storage	21 Days in Damp Sand	3 Days in Damp Sand	Air Storage	Damp Sand Storage	21 Days in Damp Sand	3 Days in Damp Sand	Air Storage	Damp Sand Storage	21 Days in Damp Sand	3 Days in Damp Sand	Air Storage
			3 Hours				**6 Hours**				**24 Hours**			
Pebbles........	.90	.66	3.17	3.93	6.41	8.09	3.81	4.49	7.70	9.53	4.99	6.26	8.84	11.00
Cr. Limestone..	.90	.66	4.66	.....	.....	.....	5.15	.....	.....	.....	6.52	.....	.....	.....
Pebbles........	1.00	.73	4.47	4.00	6.71	7.32	5.05	4.50	7.96	8.74	6.11	6.05	9.59	9.61
Cr. Limestone..	1.00	.73	2.53	.....	.....	.....	3.47	.....	.....	.....	4.71	.....	.....	.....
Pebbles........	1.10	.81	2.58	5.07	8.18	10.30	4.77	6.06	9.58	10.66	5.11	8.00	10.60	11.80
Cr. Limestone..	1.10	.81	2.89	.....	.....	.....	4.16	.....	.....	.....	4.75	.....	.....	.....
Pebbles........	1.25	.91	5.56	4.23	8.52	10.20	5.48	5.82	9.91	11.40	5.99	7.67	10.80	12.10
Cr. Limestone..	1.25	.91	4.30	.....	.....	.....	5.27	.....	.....	.....	6.02	.....	.....	.....
Pebbles........	1.35	.99	4.58	6.25	11.90	10.70	5.97	7.63	12.81	11.61	7.21	9.86	13.60	11.90
Cr. Limestone..	1.35	.99	4.72	.....	.....	.....	6.23	.....	.....	.....	7.40	.....	.....	.....
Pebbles........	1.50	1.09	4.58	6.36	9.11	11.60	6.56	7.85	11.92	13.65	7.16	10.90	13.50	14.30
Cr. Limestone..	1.50	1.09	5.07	.....	.....	.....	5.52	.....	.....	.....	8.44	.....	.....	.....
			48 Hours				**3 Days**				**7 Days**			
Pebbles........	.90	.66	5.08	6.76	9.06	11.36	6.08	7.06	9.35	11.75	6.46	7.31	9.44	11.16
Cr. Limestone..	.90	.66	6.74	.....	.....	.....	6.03	.....	.....	.....	6.98	.....	.....	.....
Pebbles........	1.00	.73	6.20	7.06	10.00	9.69	6.54	7.72	10.58	10.53	7.24	7.55	10.34	10.90
Cr. Limestone..	1.00	.73	4.85	.....	.....	.....	5.56	.....	.....	.....	5.76	.....	.....	.....
Pebbles........	1.10	.81	5.49	9.26	9.98	11.85	6.88	8.70	10.74	12.35	6.76	9.72	11.45	10.85
Cr. Limestone..	1.10	.81	5.26	.....	.....	.....	6.20	.....	.....	.....	6.90	.....	.....	.....
Pebbles........	1.25	.91	7.30	7.94	11.20	12.00	7.65	9.22	13.05	12.30	7.42	9.14	13.50	11.50
Cr. Limestone..	1.25	.91	6.54	.....	.....	.....	7.08	.....	.....	.....	8.06	.....	.....	.....
Pebbles........	1.35	.99	8.05	10.14	14.20	12.30	8.94	10.42	14.75	13.22	8.98	10.21	14.40	12.97
Cr. Limestone..	1.35	.99	7.91	.....	.....	.....	8.35	.....	.....	.....	8.85	.....	.....	.....
Pebbles........	1.50	1.09	8.02	10.95	13.50	14.45	8.49	11.45	13.65	14.86	9.92	10.81	12.92	14.32
Cr. Limestone..	1.50	1.09	8.82	.....	.....	.....	9.16	.....	.....	.....	9.10	.....	.....	...
			28 Days											
Pebbles........	.90	.66	9.07	7.82	9.63	12.22								
Cr. Limestone..	.90	.66	7.54	.....	.....	.....								
Pebbles........	1.00	.73	5.68	7.84	10.92	10.25								
Cr. Limestone..	1.00	.73	5.92	.....	.....	.....								
Pebbles........	1.10	.81	7.00	9.43	11.68	11.27								
Cr. Limestone..	1.10	.81	5.64	.....	.....	.....								
Pebbles........	1.25	.91	7.88	9.84	14.25	13.18								
Cr. Limestone..	1.25	.91	8.30	.....	.....	.....								
Pebbles........	1.35	.99	9.13	10.74	15.08	14.19								
Cr. Limestone..	1.35	.99	9.43	.....	.....	.....								
Pebbles........	1.50	1.09	10.15	11.72	15.40	16.50								
Cr. Limestone..	1.50	1.09	9.23	.....	.....	.....								

TABLE 6—UNIT WEIGHT OF CONCRETE.

Hand-mixed concrete.
Mix 1-4 by volume.
Weighed immediately before test at age of 4 months.
Aggregate graded 0-1¼-in.
The same sand used in all tests.
Coarse aggregate consisted of pebbles or crushed limestone of same grading.
The tests were made on 8 by 8 by 5-in. blocks and 6 by 12-in. cylinders.
Test pieces were stored for the period shown in damp sand, the remainder of the time in the air of the laboratory.
Each value is the average of 4 cylinders and 10 wear blocks.

Coarse Aggregate	Mixing Water		Weight—lb. per cu. ft.			
	Relative Consistency	Water Ratio	Damp Sand Storage	21 Da. in Damp Sand	3 Da. in Damp Sand	Air Storage
Pebbles	.90	.66	155.8	148.5	147.0	147.0
Crushed Limestone	.90	.66	152.5	....	....	....
Pebbles	1.00	.73	157.0	153.0	152.0	151.0
Crushed Limestone	1.00	.73	152.0	....	....	....
Pebbles	1.10	.81	156.9	152.0	150.5	149.8
Crushed Limestone	1.10	.81	156.0	....	....	....
Pebbles	1.25	.91	155.9	152.0	148.5	148.0
Crushed Limestone	1.25	.91	156.2	....	....	....
Pebbles	1.35	.99	156.9	152.0	149.8	150.2
Crushed Limestone	1.35	.99	155.6	....	....	....
Pebbles	1.59	1.09	154.8	149.5	148.2	148.0
Crushed Limestone	1.50	1.09	156.0	....	....	....

Appendix E.

REPORT ON SUBJECT (7).

W. M. KINNEY, Chairman, Sub-Committee.

(I)

Concrete which is allowed to dry out during the early stages of hardening has less strength and less resistence to wear than concrete provided with plenty of moisture during this period. It is just as harmful to fail to provide moisture to the hardening concrete as it is to use an excess of water in mixing.

(II)

Moisture can best be provided to hardening concrete by covering the concrete with earth, sand, straw or other moisture-retaining material and sprinkling this covering at least night and morning for from one to two weeks after the concrete has been placed. If the days are real hot, additional sprinklings during the day will be required and the covering should be thicker so that drying out will take place less rapidly. This method is particularly applicable to large areas. For other types of work the forms can be left on as long as possible, covering the surface of the concrete with tarpaulins to prevent rapid drying out at the surface. These tarpaulins can be sprinkled in warm weather.

In the case of reinforced concrete buildings, the buildings can be enclosed with canvas or other material and each floor sprinkled. Even without enclosing the structure with canvas, sprinkling will be beneficial.

Many schemes will suggest themselves to contractors, depending upon the character of work.

In a number of localities where earth covering was not available, concrete roads have been cured by the ponding method. Small dikes are built along the edge of the road and across the road every 30 or 40 feet. The space between these dikes is then flooded with water. This method would be applicable for station platforms, driveways, etc.

(III)

Concrete which has hardened with insufficient moisture can be improved somewhat by sprinkling even after it is several weeks old. However, such concrete will never reach the strength which it might have obtained had proper precaution been given in the early stages of hardening.

The most serious result from such failure to provide moisture occurs with sidewalks, floors, station platforms, etc. Several chemicals are recommended for treating such floors and seem to have some merit, although the treatment is expensive and the applications must be made at intervals. Providing moisture during the early stages of hardening gives satisfactory results and much better insurance against poor results.

REPORT OF COMMITTEE XII—ON RULES AND ORGANIZATION.

W. H. FINLEY, *Chairman;*
O. F. BARNES,
E. H. BARNHART,
W. C. BARRETT,
H. L. BROWNE,
J. B. CAROTHERS,
S. E. COOMBS,
C. DOUGHERTY,
H. H. EDGERTON,
B. HERMAN,
F. D. ANTHONY, *Vice-Chairman;*
A. J. HIMES,
F. D. LAKIN,
B. M. MCDONALD,
JOS. MULLEN,
E. T. REISLER,
W. H. RUPP,
P. T. SIMONS,
R. E. WARDEN,
Committee.

To the American Railway Engineering Association:

Your Committee was requested by the Board of Direction to report on the following subjects:

1. Make critical examination of the subject-matter in the Manual, and submit definite recommendations for changes.
2. Prepare a "Manual of Instructions for the Guidance of Engineering Field Parties."
3. Continue the study of the Science of Organization.
4. Prepare a "Manual of Rules for the Guidance of Employees of the Maintenance of Way Department."
5. Prepare rules for the construction, maintenance and operation of buildings and protective apparatus for the reduction of fire risk.
6. Prepare rules for the inspection of bridges and culverts.

The various subjects were assigned to Sub-Committees for study and report.

The Committee has held one general meeting, in addition to the meetings of the several Sub-Committees.

On Subject (1), Revision of Manual, your Committee reports that it has no changes to recommend at this time.

Subject (2), progress is reported.

Subject (3), Science of Organization, the conditions prevailing during the past year have made it impracticable to make a final report. As a matter of interest, your Committee submits in Appendix A a reprint from Engineering News-Record of December 12, 1918, containing "John D. Rockefeller Jr.'s Industrial Creed."

A large amount of work has been done on Subject (4), "Manual of Rules for the Guidance of Employees of the Maintenance of Way Department," but the data is not in shape to be presented at this meeting, and hence the Committee asks for further time in which to complete this topic.

Progress is also reported on Subjects (5) and (6).

Your Committee recommends that the same subjects be reassigned for the coming year.

Respectfully submitted,
COMMITTEE ON RULES AND ORGANIZATION.

Appendix A.

SCIENCE OF ORGANIZATION.

JOHN D. ROCKEFELLER JR.'S INDUSTRIAL CREED.*

Principles He Laid Down at the Reconstruction Congress at Atlantic City.

1. I believe that labor and capital are partners, not enemies; that their interests are common interests, not opposed, and that neither can attain the fullest measure of prosperity at the expense of the other, but only in association with the other.

2. I believe that the community is an essential party to industry and that it should have adequate representation with the other parties.

3. I believe that the purpose of industry is quite as much to advance social well-being as material well-being and that in the pursuit of that purpose the interests of the community should be carefully considered, the well-being of the employees as respects living and working conditions should be fully guarded, management should be adequately recognized and capital should be justly compensated, and that failures in any of these particulars means loss to all four.

4. I believe that every man is entitled to an opportunity to earn a living, to fair wages, to reasonable hours of work and proper working conditions, to a decent home, to the opportunity to play, to learn, to worship and to love, as well as to toil, and that the responsibility rests as heavily upon industry as upon government or society, to see that these conditions and opportunities prevail.

5. I believe that industry, efficiency and initiative, wherever found, should be encouraged and adequately rewarded, and that indolence, indifference and restriction of production should be discountenanced.

6. I believe that the provision of adequate means of uncovering grievances and promptly adjusting them is of fundamental importance to the successful conduct of industry.

7. I believe that the most potent measure of bringing about industrial harmony and prosperity is adequate representation of the parties in interest; that existing forms of representation should be carefully studied and availed of in so far as they may be found to have merit and are adaptable to the peculiar conditions in the various industries.

8. I believe that the most effective structure of representation is that which is built from the bottom up, which includes all employees, and, starting with the election of representatives in each industrial plant, the formation of joint works' committees, of joint district councils, and annual joint conferences of all the parties in interest in a single industrial corporation, can be extended to include all plants in the same industry, all industries in a community, in a nation, and in the various nations.

*Reprinted by permission from Engineering News-Record, December 12, 1918.

9. I believe that the application of right principles never fails to effect right relations; that "the letter killeth and the spirit maketh alive;" that forms are wholly secondary, while attitude and spirit are all-important, and that only as the parties in industry are animated by the spirit of fair play, justice to all and brotherhood, will any plans which they may mutually work out succeed.

10. I believe that that man renders the greatest social service who so co-operates in the organization of industry as to afford to the largest number of men the greatest opportunity for self-development and the enjoyment by every man of those benefits which his own work adds to the wealth of civilization.

REPORT OF COMMITTEE XVI—ON ECONOMICS OF RAILWAY LOCATION.

R. N. BEGIEN, *Chairman (Director)*; C. P. HOWARD, *Vice-Chairman*;
F. H. ALFRED,
A. S. BALDWIN *(Past-President)*,
WILLARD BEAHAN,
E. J. BEUGLER,
RALPH BUDD,
W. J. CUNNINGHAM,
C. F. W. FELT,
R. D. GARNER,
A. S. GOING,
A. J. HIMES,
H. C. IVES,
W. A. JAMES,
J. A. LAHMER,
FRED LAVIS,
E. H. MCHENRY,
G. A. MOUNTAIN,
EDWARD C. SCHMIDT,
A. K. SHURTLEFF *(Asst. Secretary)*,
C. H. SPLITSTONE,
M. F. STEINBERGER,
A. F. STEWART,
L. L. TALLYN,
ROBT. TRIMBLE *(Past-President)*,
W. F. TYE,
W. L. WEBB,
H. C. WILLIAMS,
M. A. ZOOK,

Committee.

To the American Railway Engineering Association:

The following subjects were assigned:

1. Make critical examination of the subject-matter in the Manual, and submit definite recommendations for changes, taking into special consideration a revision of the conclusions in Vol. 16, pages 104 to 109.
2. Report on the resistance of trains running between 35 and 75 miles per hour.
3. (a) Report on the effect of curvature on cost of maintenance of way.
   (b) Report on the effect of curvature on maintenance of equipment.
4. Report on the effect of train resistance on the amount of fuel consumed.
5. Report on the entire question of economics of location as affected by the introduction of electric locomotives.

Sub-Committees were appointed to consider each of the subjects assigned, but four of the Chairmen of Sub-Committees asked to be relieved. Only one Chairman responded that he would undertake the work, and only one Committee did any work. The report of that Committee is herewith appended.

No criticism is offered on account of the failure to devote time to the work of this Committee during the war period. Some of the members were in military service, and practically all were deep in war work throughout the entire period of time.

Respectfully submitted,

COMMITTEE ON ECONOMICS OF RAILWAY LOCATION.

Appendix A.

EFFECT OF CURVATURE ON COST OF MAINTENANCE OF WAY AND EQUIPMENT.

C. P. HOWARD, Chairman, Sub-Committee.

The subjects assigned this Sub-Committee were:

(a) Effect of curvature on cost of maintenance of way;

(b) Effect of curvature on cost of maintenance of equipment.

A meeting of members of the Sub-Committee was held at Chicago, July 23, at which were present Messrs. L. L. Tallyn, Robert Trimble and C. P. Howard.

It was decided not to circularize all the railroads, the times not being propitious, but to address officials of a few lines asking for any data they might have as to the various elements of curve expense.

(The Circular of Inquiry was published in Bulletin 210, October, 1918, pp. 79, 80.)

Several replies were received, but the only information obtained was from the Pennsylvania Lines, and is considered of such importance that it is made the basis of this report. This data is as follows:

"An investigation was made by the Pennsylvania Lines West of Pittsburgh during the years 1908 and 1911, inclusive, some of the results of which appear to throw some light upon the effect of curvature on the cost of maintenance.

"The investigation referred to was to determine as to whether or not lubrication of rails on curves would reduce rail wear and thereby result in corresponding economies. In order to present comparative estimates showing this it was necessary, so far as possible, to determine the relation between the wear of rails on straight lines as compared with wear on curved line of varying degrees.

"Table A below gives data concerning rail renewals on straight and curved track on 164 miles of the Eastern Division of the P., Ft. W. & C. Railway from Rochester to Crestline, for a period of thirty-one years.

TABLE A.

	Average Length of Track	Length of Track Renewed in 31 Years	Number of Renewals in 31 Years	Average Life, Years	Ratio of Renewals Tangent Being Equal to 1
Tangent	1,037,633	2,988,561	2.88	10.76	1.00
Curve.........0° to 10°	117,107	332,539	2.84	10.90	.99
Curve.........1° to 2°	157,323	510,289	3.24	9.57	1.12
Curve.........2° to 3°	79,847	267,823	3.35	9.25	1.16
Curve.........3° to 4°	46,384	186,291	4.01	7.73	1.39
Curve.........4° to 5°	34,819	153,764	4.42	7.04	1.53
Curve.........5° to 6°	4,580	24,146	5.27	5.90	1.82

"On account of the physical characteristics of the portion of the road investigated there is no data covering curves over six degrees. The information contained in this table has been plotted graphically, and an effort has been made to plot a curve showing a fair average of the results obtained. (See Diagram.)

"Table B below gives the length in miles and percentages of straight and curved track on the Pennsylvania Lines West for all main tracks.

TABLE B.

	ROAD		ALL TRACKS	
	Miles	Per Cent.	Miles	Per Cent.
Straight	2212	80.9	3365	78.4
Curves 2 degrees and under	269	9.8	487	11.3
Curves over 2 degrees, under 4 degrees	168	6.1	286	6.6
Curves 4 degrees and over	83	3.0	151	3.5
Total—Curved	520	19.1	924	21.5
Total—Straight and Curved	2733	100.0	4289	100.0

"The ratio of wear for different degrees of curve has been combined with the lengths and percentages of straight and curved track and these results are shown in Table C below.

TABLE C.

Number of Miles		Ratio of Wear	Equivalent Miles of Straight Track
3365	Straight	1.00	3365
487	Curves 2 degrees and under	1.10	536
286	Curves 2 and under 4 degrees	1.30	372
151	Curve over 4 degrees	1.60	242
4289		1.076	4515

"This table indicates that the increased wear of rail due to curvature is about 7.6 per cent.

"The result as developed in Table C would have been more accurate if the length of curves had been given by increments of one degree instead of 2 degrees. Inasmuch as it would require considerable work to make this separation it was deemed unnecessary in the present case to go to this trouble.

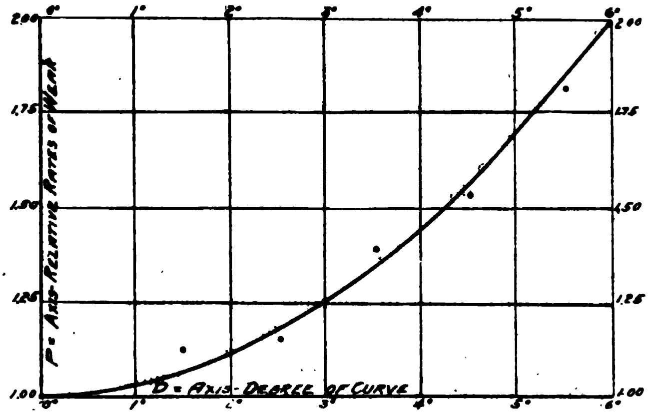
"It would seem * * * a fair assumption that other maintenance of way expenses due to curvature would increase in about the same proportion as that for renewals of rails and that the expenses will vary on each line or part of line according to the amount and degree of curve."

It will be noted that the average increase in rail wear on curves as compared with tangents is about 100 per cent. for a six-degree curve; 25 per cent. for a three-degree, etc., or approximately as the square of the degree of curve. The importance of this information is evident when it is remembered that heretofore it has been customary to estimate curve expense directly with the central angle, or with the degree of curve when a given length is considered.

It has been suggested that it would be a fair assumption that other maintenance of way expenses due to curvature would increase in about the same proportion as that for renewals of rails. Your Committee feels, however, that though such a tendency may be approximately true

for some expenses of maintenance, it would be more conservative to submit at this time such actual data as has been secured, hoping that further investigations and additional information will enable them to formulate with greater confidence and point out such parallels where they exist.

The Committee has no conclusions to submit at this time.



P = Percentage of Increase
D = Degree of Curve

Formula

$$P = \frac{25D^2}{9}$$

DIAGRAM SHOWING RELATION BETWEEN WEAR OF RAIL ON STRAIGHT LINE AS COMPARED WITH THAT ON CURVES BASED ON RECORDS OF PENNSYLVANIA LINES WEST OF PITTSBURGH

November 1918

REPORT OF COMMITTEE XXII—ON ECONOMICS OF RAILWAY LABOR.

E. R. LEWIS, *Chairman;*
W. J. BACKES,
R. A. BALDWIN,
J. Q. BARLOW,
A. F. BLAESS,
W. M. CAMP,
W. R. DAWSON,
R. C. FALCONER,
R. H. FORD,
W. R. HILLARY,
C. B. HOYT,
C. H. STEIN, *Vice-Chairman;*
W. H. HOYT,
E. D. JACKSON,
C. M. JAMES,
C. E. JOHNSTON,
A. C. MACKENZIE,
*JOHN C. NELSON,
C. A. PAQUETTE,
J. W. PFAU,
H. R. SAFFORD,
†LIEUT.-COL. H. J. SLIFER,
Committee.

To the American Railway Engineering Association:

Your Committee on Economics of Railway Labor submits its report to the Twentieth Annual Convention.

The following subjects were assigned your Committee by the Board of Direction:

1. Report on plans and methods for organizing to obtain labor for railways.
2. Report on methods of equating track sections.
3. Report on typical plans for boarding cars and boarding houses for railway laborers, conferring with Committee on Buildings.
4. Study the matter of establishing proper relations between unit of track expenditure and unit per mile of line for different classes of road for the purpose of determining a normal maintenance expense and to obtain as far as possible uniform conditions involving: (a) Separation of expenses as between Road, Signal and Bridge and Building Departments; (b) The determination of the ratio of labor cost to total cost.
5. Report on labor-saving devices.

COMMITTEE MEETINGS.

Meetings of the whole Committee were held in Chicago on June 11, September 10 and November 8, in addition to the meetings held by the various Sub-Committees.

(1) REPORT ON PLANS AND METHODS FOR ORGANIZING TO OBTAIN LABOR FOR RAILWAYS.

Your Committee has considered this subject and finds that under present circumstances it seems advisable to continue investigation before presenting any set plan of organization for your consideration. Your Committee reports progress on this subject.

*Died, October 6, 1918. †Died in France, February 3, 1919.

(2) REPORT ON METHODS OF EQUATING TRACK SECTIONS.

Your Committee presents in Appendix "A" its report on the methods now in use.

(3) REPORT ON TYPICAL PLANS FOR BOARDING CARS AND BOARDING HOUSES FOR RAILWAY LABORERS, CONFERRING WITH COMMITTEE ON BUILDINGS.

Your Committee presents in Appendix "B" tentative outline plans with explanations, with a view to criticism before taking up detail drawings.

(4) STUDY THE MATTER OF ESTABLISHING PROPER RELATIONS BETWEEN UNIT OF TRACK EXPENDITURE AND UNIT PER MILE OF LINE, FOR DIFFERENT CLASSES OF ROAD FOR THE PURPOSE OF DETERMINING A NORMAL MAINTENANCE EXPENSE AND TO OBTAIN, AS FAR AS POSSIBLE, UNIFORM CONDITIONS INVOLVING (a) SEPARATION OF EXPENSES AS BETWEEN ROAD, SIGNAL AND BRIDGE AND BUILDING DEPARTMENTS; (b) THE DETERMINATION OF THE RATIO OF THE LABOR COST TO TOTAL COST.

Your Committee presents in Appendix "C" a study of this subject as a progress report.

(5) REPORT ON LABOR-SAVING DEVICES.

Your Committee presents in Appendix "D" a list of 60 labor-saving devices with short descriptions of these machines and their purposes.

CONCLUSIONS.

Your Committee recommends:

Subject (2). That the report on methods of equating track sections be accepted as information and printed in the Proceedings.

Subject (3). That the report on typical plans for boarding cars and boarding houses for railway laborers be received as a progress report. (To be considered further at the next convention.)

Subject 4. That the study of relations of units of track expenditure to units of mile of line with view of determining a normal maintenance expense and to obtain, as far as possible, uniform conditions involving (a) Separation of expenses as between Road, Signal and Bridge

and Building Departments; (b) The determination of the ratio of labor cost to total cost, be received as a progress report.

RECOMMENDATIONS FOR FUTURE WORK.

Your Committee recommends for next year's work: continuation of subjects (1), (3) and (4).

Respectfully submitted,

COMMITTEE ON ECONOMICS OF RAILWAY LABOR.

Appendix A.

(2) EQUATING TRACK SECTIONS.

E. T. HOWSON, *Chairman;*
H. R. SAFFORD,
R. H. FORD,
C. H. STEIN,
R. A. BALDWIN,
C. M. JAMES,
Sub-Committee.

Labor constitutes the largest single item of maintenance of way expense; in fact, it is larger than all other expenditures combined, aggregating approximately 56 per cent. of all charges of this department. From its nature it is the expenditure in which there is the greatest opportunity for the display of economy and likewise the greatest danger of waste and inefficiency. It would, therefore, naturally be expected that the distribution of this expenditure, aggregating over one-half million dollars a day, would be surrounded with elaborate safeguards to insure the greatest return. Yet investigation shows that the reverse is true. As a result, the allotments are commonly made on an arbitrary basis of so many men per section, with only very general consideration of the relative amounts of work to be done.

In the discussion of labor distribution the gang is the unit in the maintenance of way organization. As the larger part of the employees in this department are engaged in track maintenance and are employed in section gangs, the Committee has confined its discussion to this class of work, although the general principles apply equally to other maintenance work.

In general, section limits have been established by giving each gang an equal mileage of main line with whatever auxiliary tracks come between these limits. The gangs are then allowed an equal number of men. The result is that some gangs have much more work to perform than others because of unequal mileages of sidetracks and special local conditions. With an unequal distribution of the work, it is evident that the greatest return is not being secured from the total expenditure and loss occurs.

The importance of equating sections on a more equitable basis has been recognized for years and some study has been given to its solution. As a result, certain more or less arbitrary ratios have been established on a few roads, and while perhaps crude and inaccurate, are a step in advance of the common practice.

Thus, on the New York Central two miles of sidetracks, or 15 switches, are considered equivalent to one mile of main track. Allowance is also made for special local conditions, such as soft subgrade, high rock cuts, excessive curvature, character of traffic, etc. An ordinary section is given about six equated miles of main track.

On the Southern Pacific two miles of branch lines, or four miles of sidings, are considered equivalent to one mile of main line. Sixteen

switches are also considered equivalent to one mile of track of the kind in which the switches are placed. Consideration is also given to the nature of the rail, ballast, curvature, density of traffic, etc.

On the Cleveland, Cincinnati, Chicago & St. Louis track sections have been equated where the line has been double-tracked, the length of such sections being made equivalent to six miles of single track on the following basis: Second track, 85 per cent. of main track; passing tracks, 50 per cent. of main track; yard tracks in heavy terminal yards, 50 per cent.; other sidetracks, 30 per cent.; turnouts, each equivalent to 300 ft. of main track.

On the New York, New Haven & Hartford a mile of main track has been taken as a unit. Two miles of sidetrack, or 15 switches, are considered equivalent to one mile of main track. The various lines of this road have been classified between main line, secondary main line, and branches, partially on the basis of the tonnage passing over them and in part on the importance of the lines from a passenger standpoint where the tonnage alone is not sufficiently heavy to bring them into what is considered the proper class. Different allowances of men per equated track mile are made on the lines of these different classes, consideration being given to the fact that on divisions of two and four tracks the shorter distance sectionmen have to go compensating them slightly for the heavier traffic.

An equation was worked out on one division of the Michigan Central about five years ago, covering 300 miles of single main track and 500 miles of branch tracks and sidings. As the result of a 12 months' study of the actual distribution of work on this division, the following relations were established, one mile of single main track being considered as the unit:

One mile of single main main track, Class "B"	100	per cent.
One mile of single branch track	65	" "
One mile of passing track	46	" "
One mile of yard track	32.4	" "
One mile of industrial track	24	" "
One main track turnout	3.4	" "
One side track turnout	1.4	" "
One railroad crossing (one track crossing only)	3.1	" "
One highway crossing (highway over one track)	2.0	" "
One mile of fence (one side)	2.7	" "
One mile of right-of-way (100 ft. wide)	4.2	" "
One farm crossing (over one track only)	0.4	" "

On the Toledo division of the Pennsylvania Lines West of Pittsburgh, consisting almost entirely of single track, with only a small amount of second track, one mile of main track is considered equivalent to three miles of sidetracks, four miles of yard tracks, 20 main line turnouts, 40 turnouts in side and yard tracks, 25 railroad crossings, 40 public highway crossings and 60 private crossings.

The Baltimore & Ohio has given careful attention to the subject of equating track sections in connection with the development of its stand-

ard track work system, as the determination of standard performances is essential to the computation and payment of bonuses. The details of this system, including the determination of units of track work, were described in a monograph by Earl Stimson, published in the Proceedings of this Association for 1916.

The Grand Trunk has given careful consideration to this problem. Based upon its extended studies, the following basis has been approved for equating track forces:

2	miles of passing track	=	1 mile of main track
2½	miles all other sidings	=	" " " "
15	switches	=	" " " "
24	single derails connected with tower or switch stand	=	" " " "
12	single track railway crossings	=	" " " "
15	single highway crossings (public roads)	=	" " " "
10	single highway crossings (city streets)	=	" " " "

STANDARD FORCE.

Class.		Force—1 Foreman and	Equiv. mileage of section.	Men per mile with foreman.	Men per mile without foreman.	Miles per man with foreman.	Miles per man without foreman.
A. Double track lines	S	6 men	9	0.78	0.67	1.29	1.50
	W	3 men		0.44	0.33	2.25	3.00
A. Single track lines	S	4 men	6	0.83	0.66	1.20	1.50
	W	3 men		0.66	0.50	1.50	2.00
B. Single track lines	S	4 men	7	0.71	0.57	1.40	1.75
	W	3 men		0.57	0.43	1.75	2.33
C. Single track lines	S	3 men	8	0.50	0.37	2.00	2.67
	W	2 men		0.37	0.25	2.67	4.00

Each supervisor has a permanent extra gang on his district, based on the following percentage of the actual main line and siding mileage (not equated):

Class A	Summer	10 per cent.
	Winter	5 per cent.
Class B and C	Summer	6 per cent.
	Winter	3 per cent.

CLASSIFICATION OF TRACK.

Class A—Railways having more than one track, or a single track with the following traffic per mile:
Freight cars per year = 150,000 or 5,000,000 tons.
Passenger cars per year = 10,000.
Maximum passenger speed of 50 miles per hour.

Class B—Single track lines having the following traffic per mile:
Freight cars per year = 50,000 or 1,670,000 tons.
Passenger cars per year = 5,000.
Maximum passenger speed of 40 miles per hour.

Class C—Single track lines not meeting the minimum requirements of class B.

An analysis of the cost of maintenance of way and structures for the purpose of establishing the proper relations between expenditures per mile of line and per unit of track for different classes of roads has been made recently for six sub-divisions of one of the roads represented on the Committee. As Sub-Committee (4) of this Committee is reporting on the former phase of this problem the entire analysis is published with that report.

Starting about four years ago the Track Committee undertook the compilation of data showing the actual distribution of the work on a number of representative sections on different roads in various parts of the country. On the organization of the Committee on Economics of Railway Labor this work was transferred to it and this Committee has continued to receive and to study the reports sent in monthly by those roads which are coöperating in the collection of the data. As the consideration of these reports has progressed, the Committee has become convinced of the impossibility of its making a proper analysis of the statistics because of the many local factors which are present on an individual road and which affect the results to a marked degree. The Committee, therefore, believes that the reports of the test sections should be returned to the individual roads for analysis and for the development of the correct formulas. The Committee has found it impossible to furnish and establish uniform formulas because of these local variable factors.

Twenty-one railroads volunteered originally to compile this record. On account of war and other conditions, all but four railroads have discontinued sending in this data.

Appendix B.

(3) TYPICAL PLANS FOR HOUSING LABOR.

A. F. BLAESS, *Chairman;*
W. H. HOYT,
E. D. JACKSON,
W. R. HILLARY,
JOHN C. NELSON,
J. W. PFAU,
Sub-Committee.

(3) Your Committee reports progress, having prepared and presenting for consideration the following tentative typical plans for housing maintenance of way labor:

1. Knockdown Portable Bunk House—8 men..Floor Plan and Section
2. Knockdown Portable Bunk House—16 men..Floor Plan and Section
3. Septic closet for use with knockdown or permanent camp ....Floor Plan and Section

Camp Cars.

4. Sleeping Car ....Floor Plan Only
5. Foreman's and Commissary Car ....Floor Plan Only
6. Kitchen Car ....Floor Plan Only
7. Dining Car ....Floor Plan Only
8. Material Car ....Floor Plan Only

Knockdown Camps.

9. Washroom and toilet building ....Floor Plan and Section
10. Mess Hall ....Floor Plan and Section
11. Bunk House ....Floor Plan and Section
12. Lounging Building ....Floor Plan and Section
13. Commissary Store ....Floor Plan and Section
14. Isolation Building ....Floor Plan and Section

Permanent Camps.

15. Commissary Store ....Floor Plan and Section
16. Isolation Building ....Floor Plan and Section
17. Mess Hall ....Floor Plan and Section
18. Bunk House ....Floor Plan and Section
19. Lounging Building ....Floor Plan and Section
20. Washroom and Toilet Building..............Floor Plan and Section

The units for 8 to 16 men are intended for isolated places where it is desired to enlarge the gang and where other accommodations for laborers are not available, such as section headquarters at out-of-the-way places.

The septic closet is intended for use in connection with any of the above plans, except the camp cars, which are usually moved too often to justify construction of elaborate facilities. The pit can be made of timber or concrete, according to the length of time it is expected to be used. The building can be readily moved and only the pit is stationary.

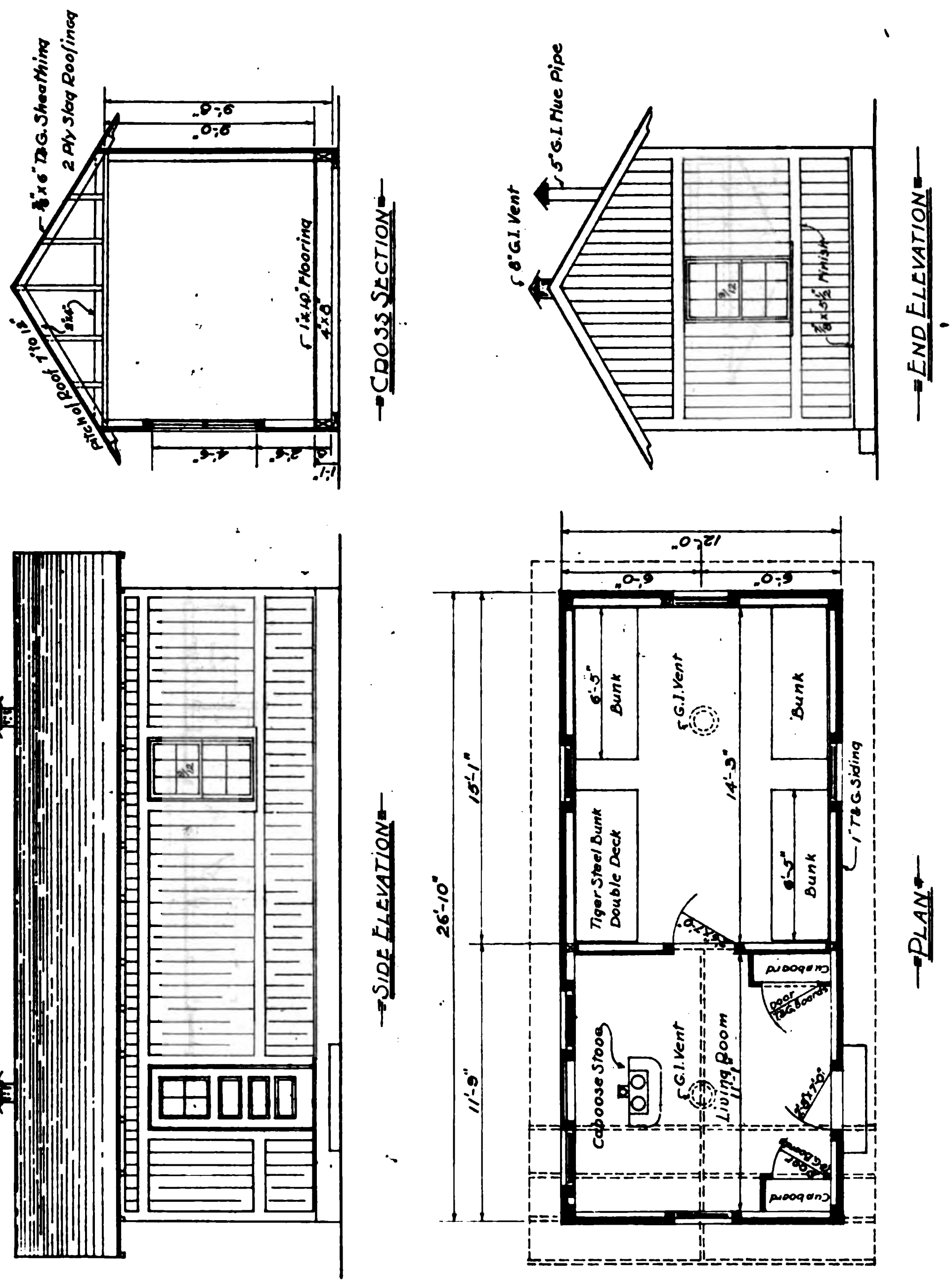
The camp car outfits are for gangs frequently moving. The question of ceiling or lining the cars will depend upon the class of labor and the locality, but the Committee feels that the prevailing idea should be to make the quarters for the men comfortable and as attractive as consistent.

The knockdown portable camps are intended for use at points where large gangs will be required for a year or two, after which time they may be moved to other points. These camps may be provided with electric lights and sanitary sewage facilities where available. These features will, however, depend on the advantages and ordinances of the particular locality. In general this construction consists of building sections bolted together, but this is not shown in detail on the plans, since this is a feature to be worked out with the Committee on Buildings.

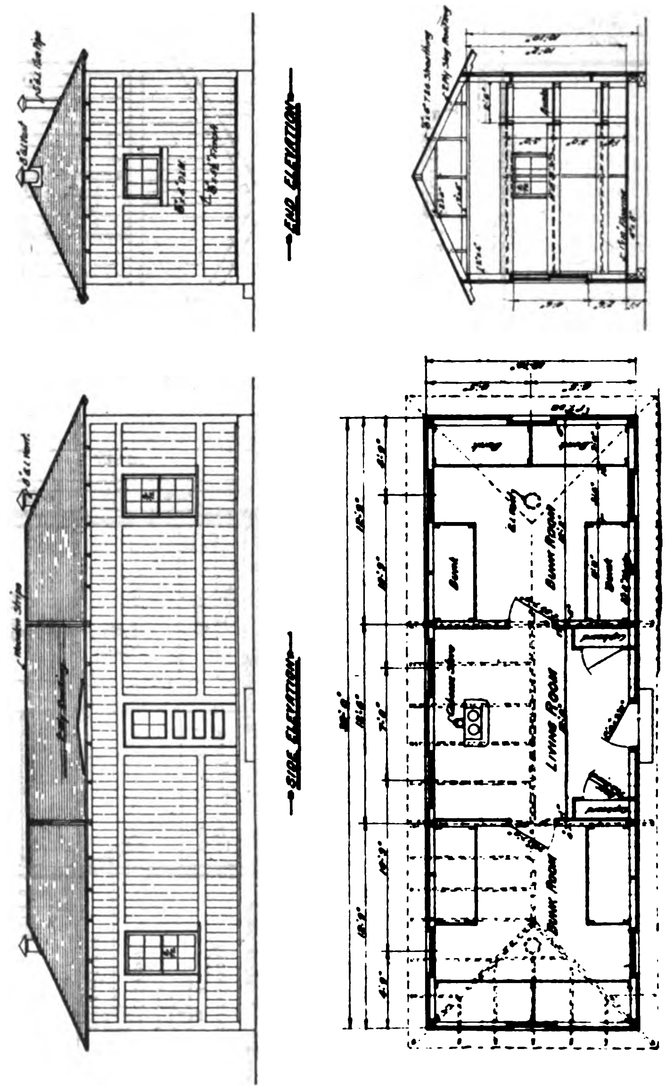
The bunk house plans do not show lockers. These can be provided, however, as shown in the plan for permanent camp. The floors of these buildings, as well as the permanent camps, are placed about two feet above the ground for ventilation, and it is suggested that during the winter months, if necessary, this opening be banked up with earth in order to make the building warmer. The lounging building shown is the same as bunk house, except for the equipment, and is so constructed in order that it may be readily converted into an additional bunk unit by removing the tables and installing bunks.

The description of the portable camp will apply also to the permanent camp, except that in the permanent camp lockers have been shown in the bunk house and the washroom has been provided with a mastic floor.

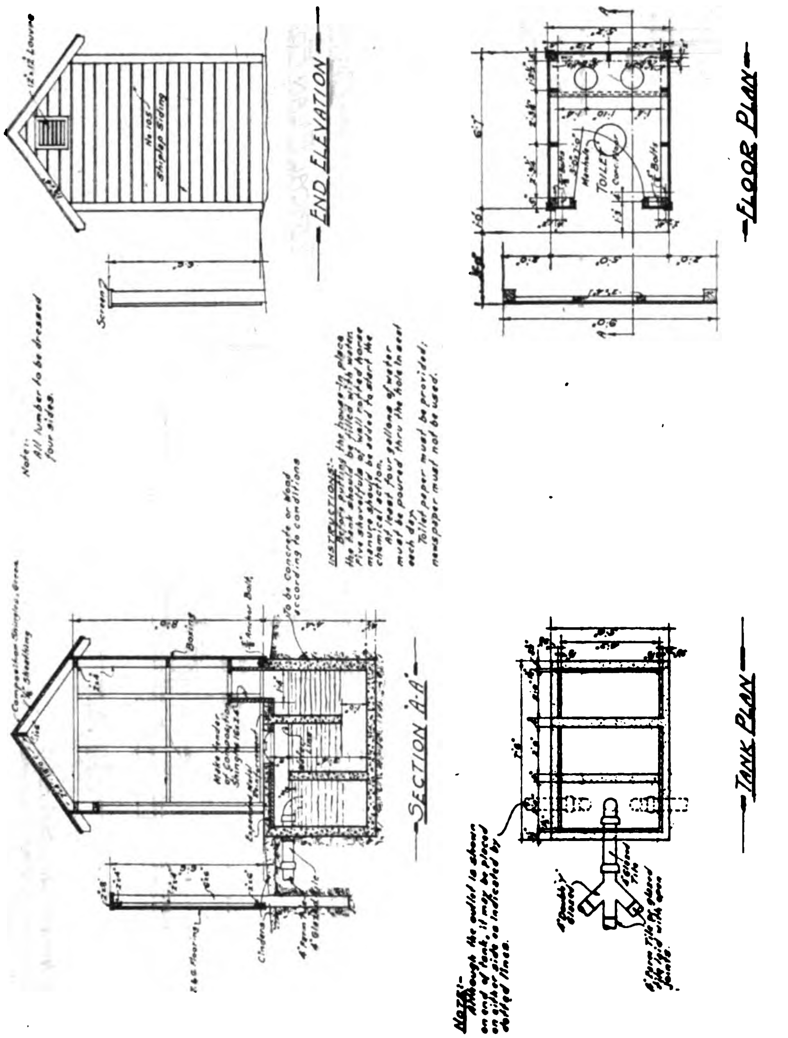
These plans are intended merely to give a general idea of the type and arrangement of buildings most suitable for the purpose mentioned, and no attempt has been made to work out the details of construction. Before submitting the plans to the Association for final approval, the plans will be submitted to the Committee on Buildings for the preparation of detailed plans, but it is felt that unnecessary work for that Committee may be prevented by reaching an agreement on the general plans before they are submitted to the Buildings Committee. This Committee proposes to ask for written criticisms on these plans during the ensuing year.



CROSS SECTION
END ELEVATION
SIDE ELEVATION
PLAN
¾"x6" T&G. Sheathing
2 Ply Slag Roofing
Pitch of Roof 7" to 12"
1"x4" Flooring
8" G.I. Vent
5" G.I. Flue Pipe
Tiger Steel Bunk Double Deck
Bunk
G.I. Vent
Caboose Stove
Living Room
Cupboard
1" T&G Siding
26'-10"
15'-1"
11'-9"
12'-0"
14'-5"

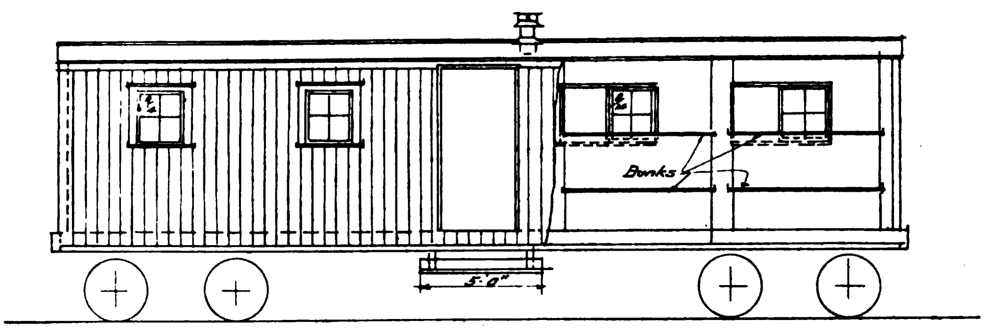


KNOCKDOWN PORTABLE BUNK HOUSE—TYPICAL PLAN FOR SMALL ISOLATED UNITS.

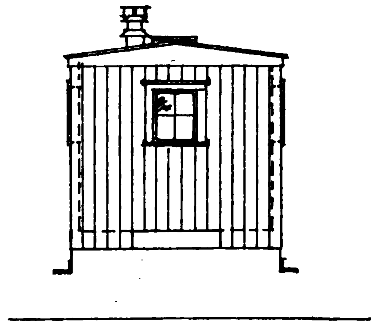


Note:—Additional units may be built where necessary.

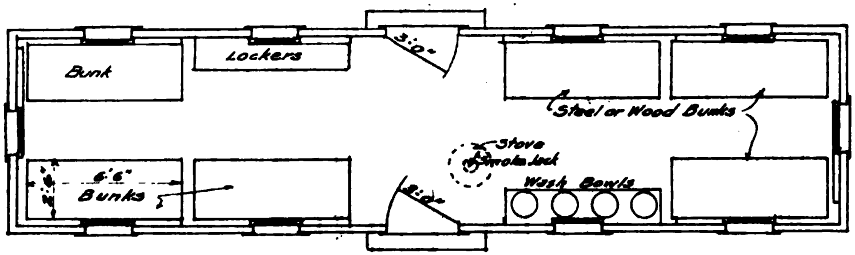
TYPICAL PLAN FOR A SEPTIC CLOSET.



SIDE ELEVATION.



END ELEVATION

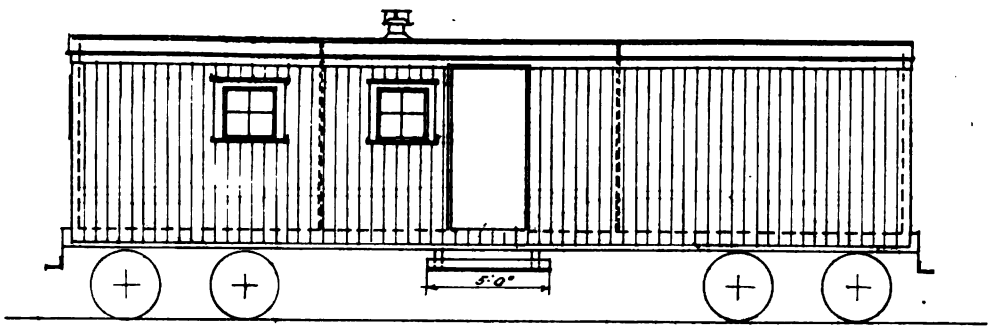


PLAN.

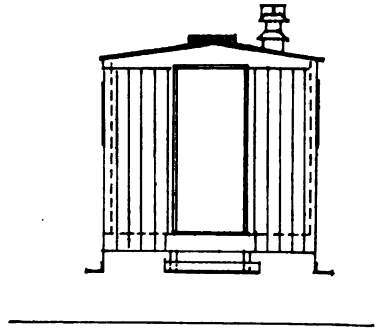
NOTE: All Window Sash 33½" x 20¼"
All Windows & Doors screened.
Car painted inside
Windows in this car to be placed on the belt,
or as low as the construction of the car will permit.
Car not to be ceiled or lined.

CAMP CARS

TYPICAL PLAN FOR SLEEPING CAR



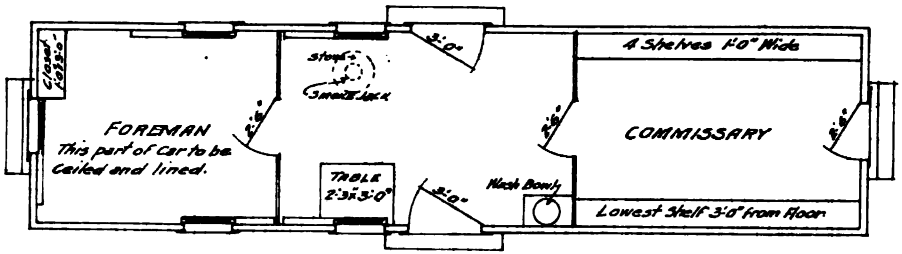
— SIDE ELEVATION —



— END ELEVATION —

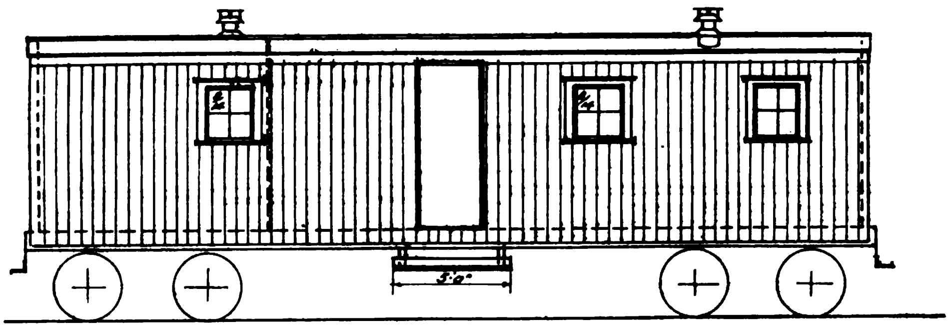
— CAMP CARS —

— TYPICAL PLAN FOR FOREMAN & COMMISSARY CAR —

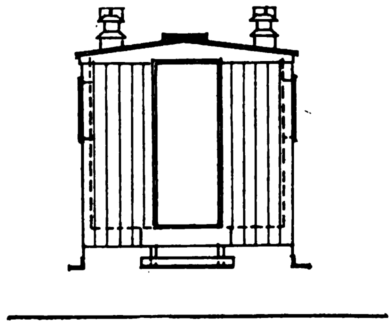


— PLAN —

NOTE: All Window Sash 33½" x 20" x ⅞"
All Windows & Doors screened.
Car painted inside.
Car not to be ceiled or lined except as noted.



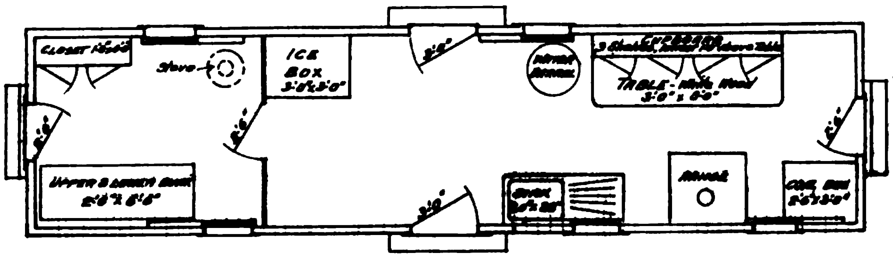
SIDE ELEVATION



END ELEVATION

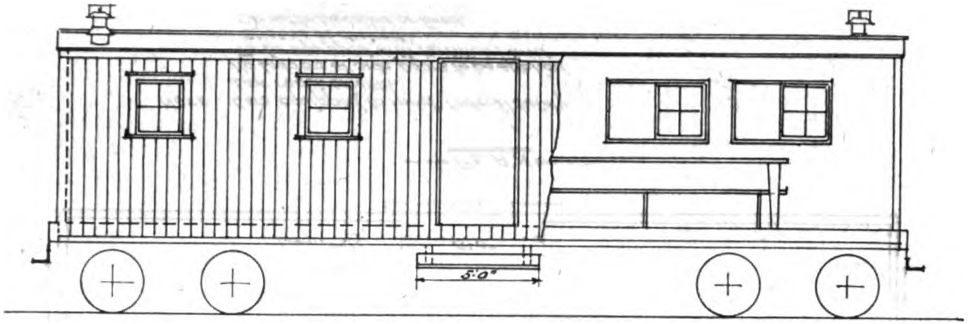
CAMP CARS

TYPICAL PLAN FOR KITCHEN CAR

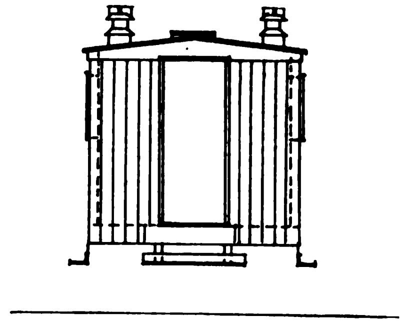


PLAN

Note: All Window Sash [illegible]
All Windows & Doors screened.
Car painted inside.
Car not to be ceiled or lined.



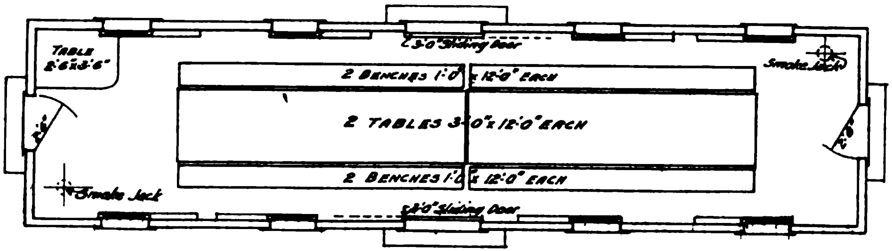
SIDE ELEVATION.



END ELEVATION.

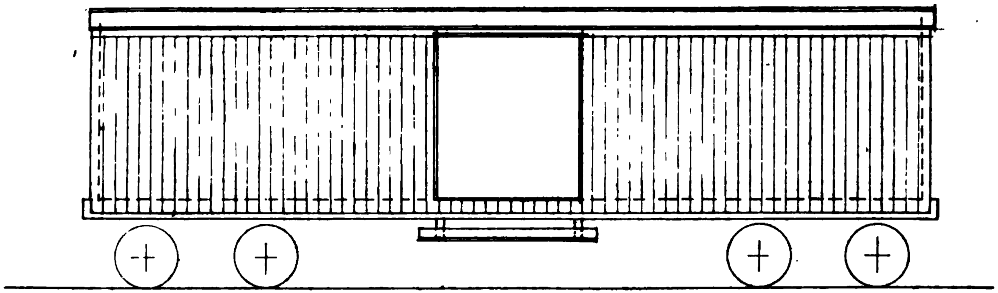
CAMP CARS

TYPICAL PLAN FOR DINING CAR

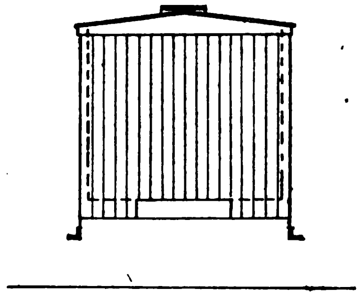


PLAN

NOTE: All Window Sash 33½" x 20" x 1⅜"
All Windows & Doors screened.
Car painted inside.
Car not to be ceiled or lined.



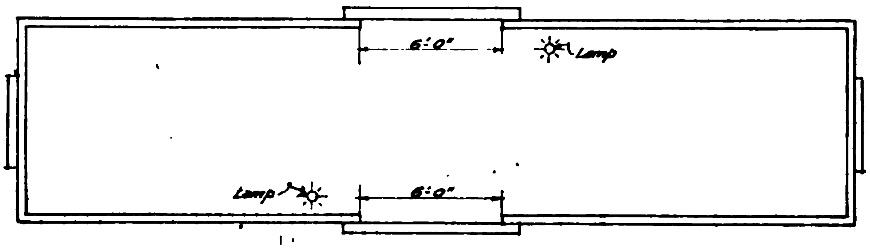
SIDE ELEVATION



END ELEVATION

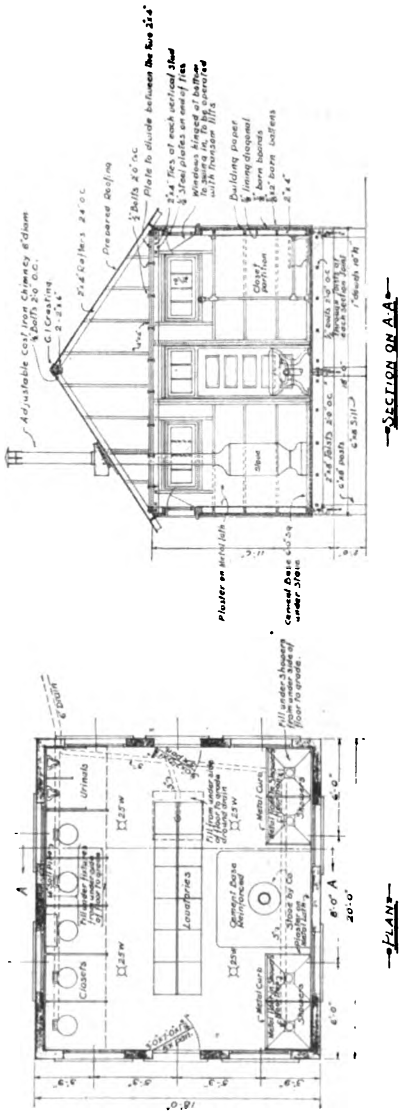
CAMP CARS

TYPICAL PLAN FOR MATERIAL CAR

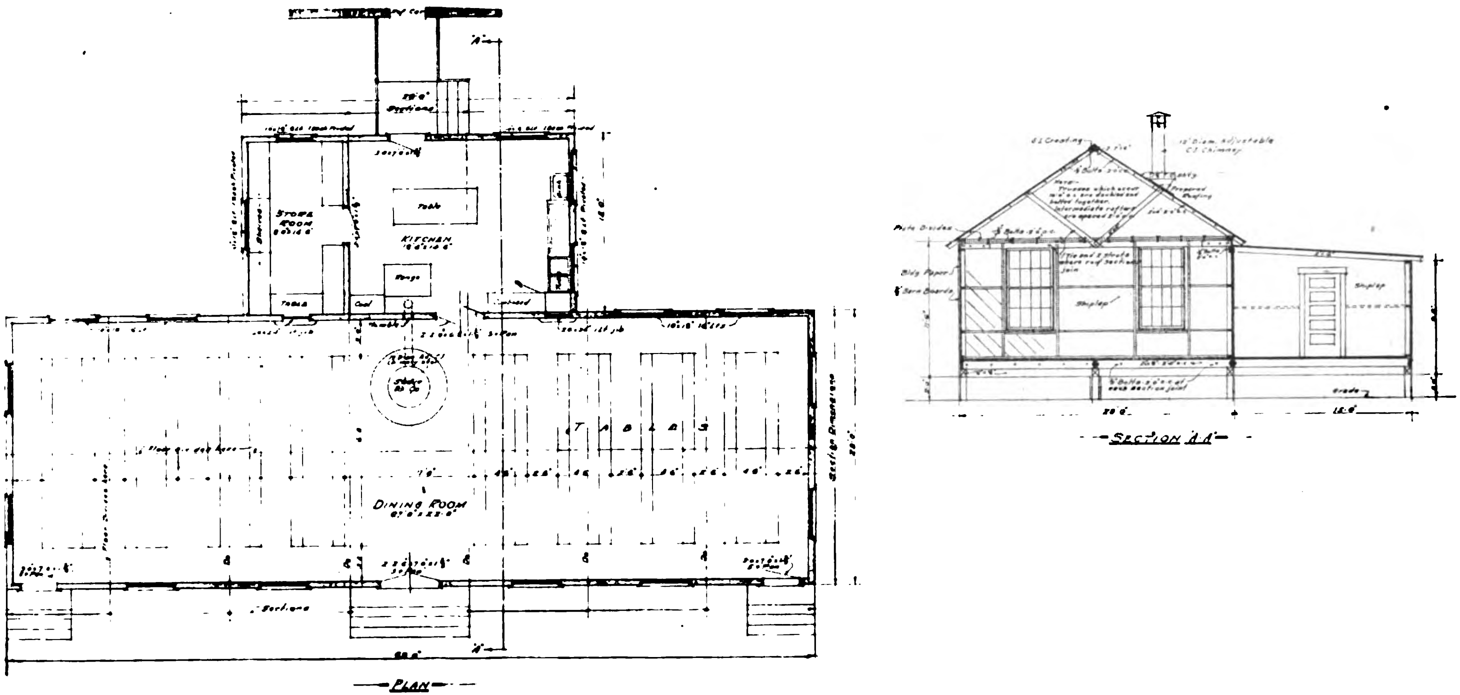


PLAN

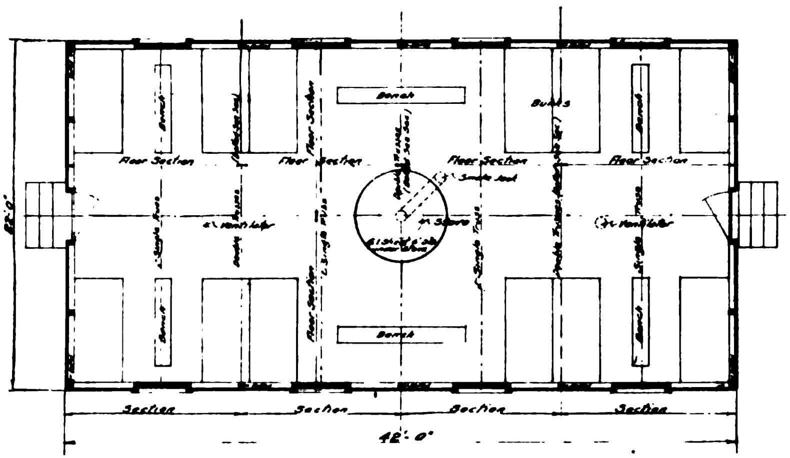
NOTE: Cars equipped to meet Federal Safety Law requirements.
No Ladders at side Doors to be applied.
To be equipped with Partitions and Shelves as desired.
Car not to be ceiled or lined.



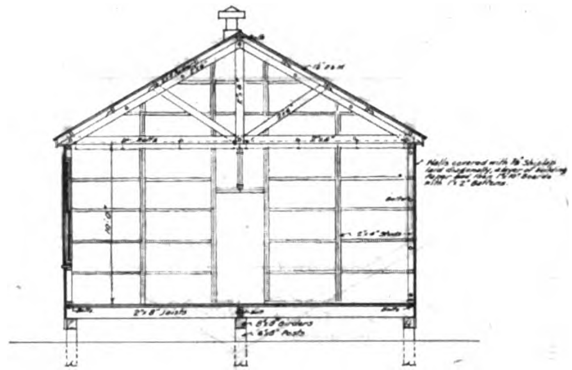
Knockdown Portable Camp—Typical Plan for Wash Room and Toilet Building.



TYPICAL PLAN FOR MESS HALL

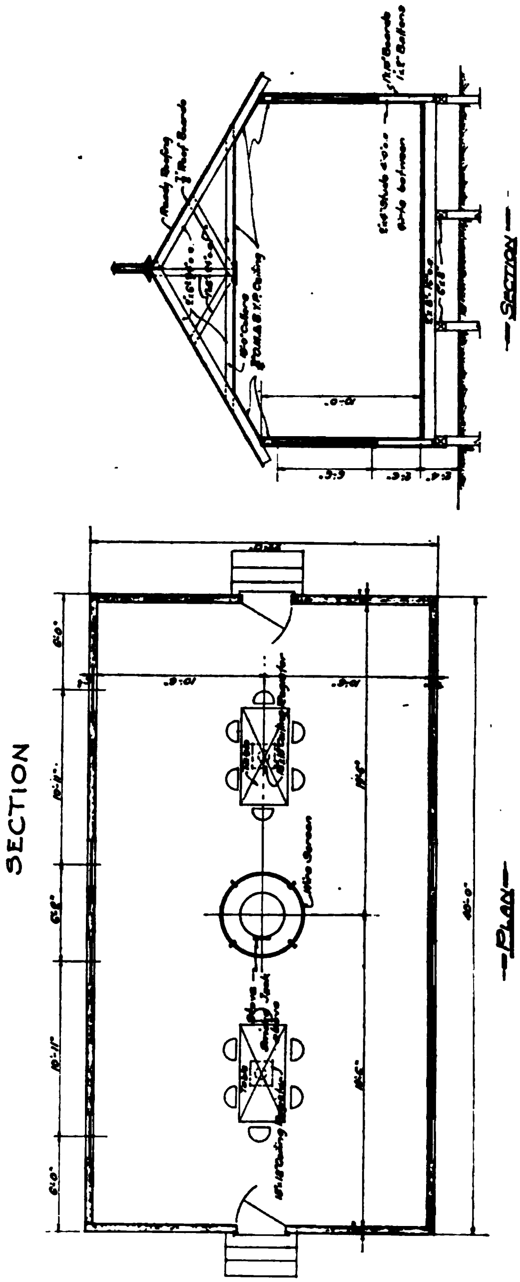


—PLAN—

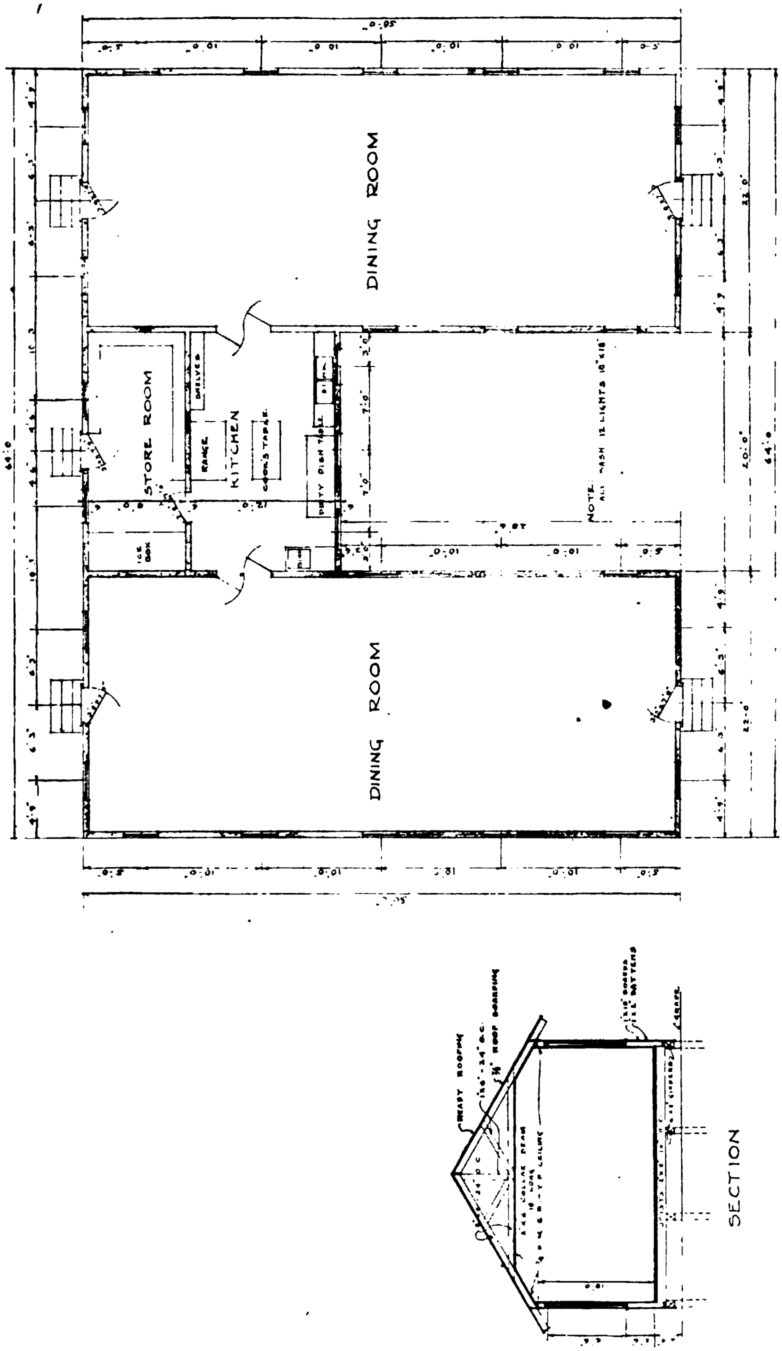


—CROSS SECTION—

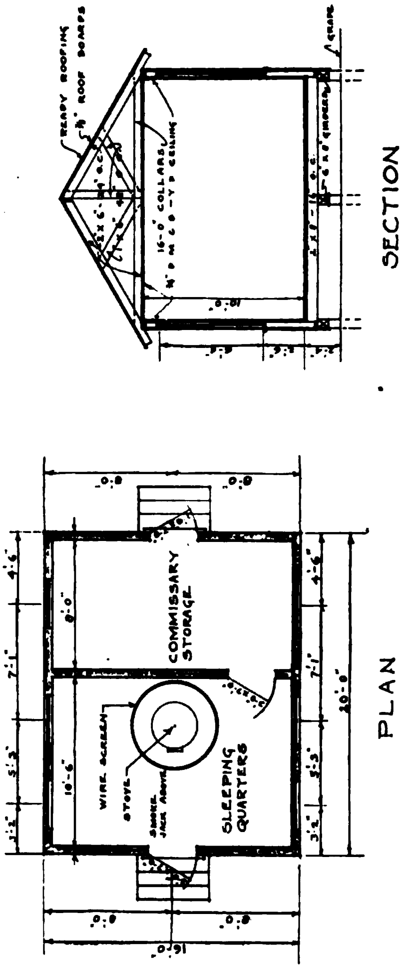
Typical Plan for Bunk House.



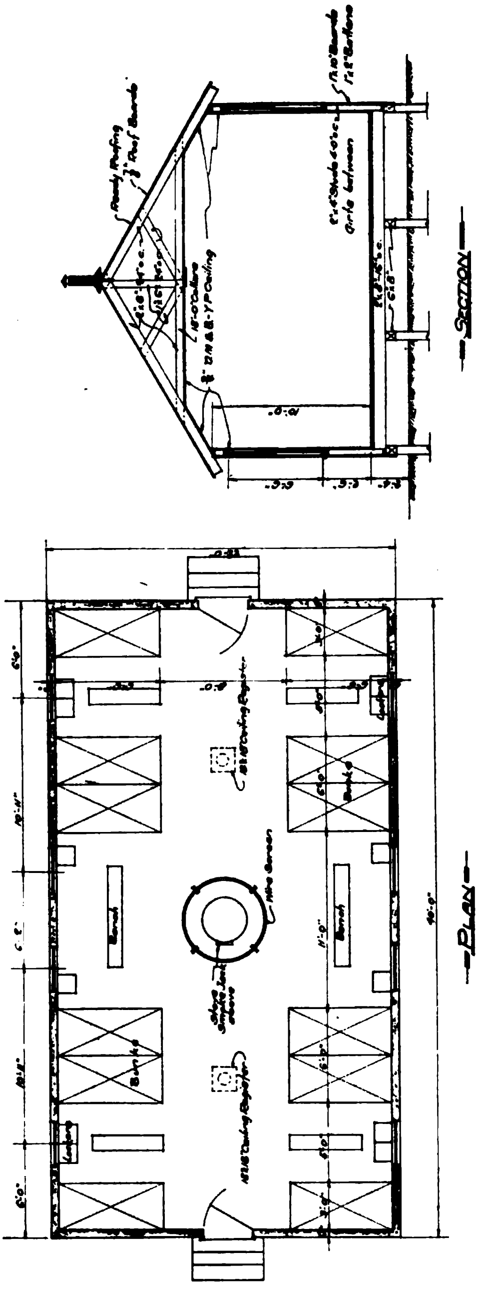
Knockdown Portable Camp—Typical Plan for Lounging Building.



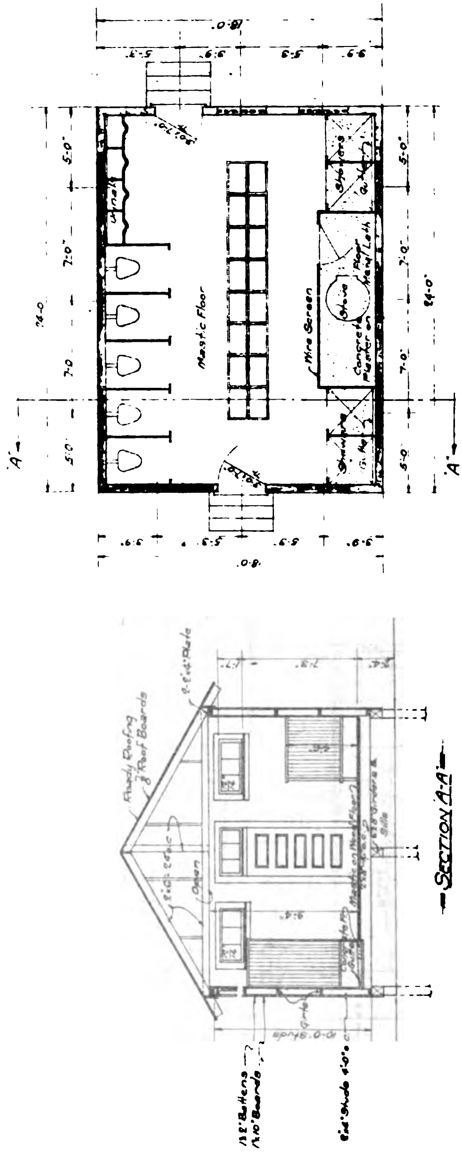
PERMANENT CAMP—TYPICAL PLAN FOR MESS HALL BUILDING.



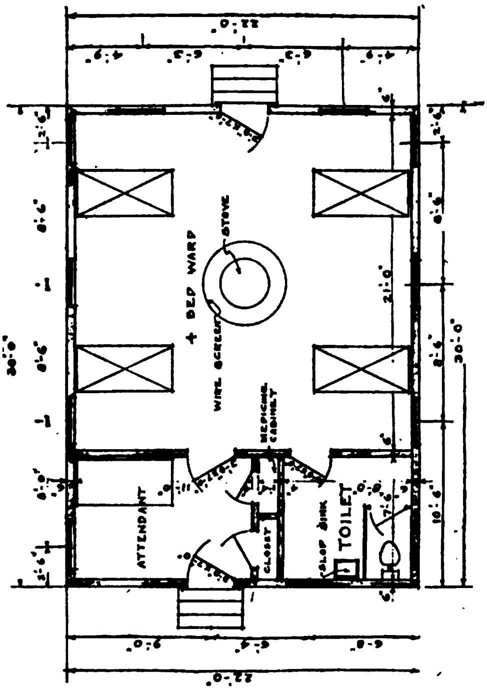
Typical Plan for Isolation Building.

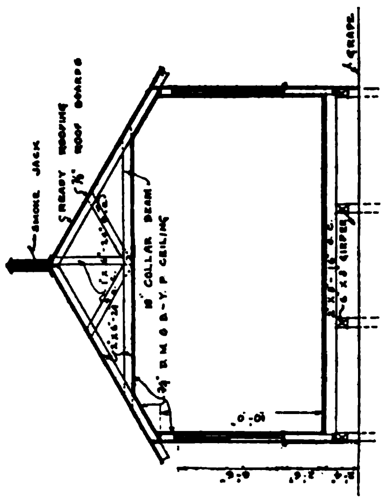


PERMANENT CAMP—TYPICAL PLAN FOR BUNK HOUSE.



PERMANENT CAMP TYPICAL PLAN FOR WASHROOM AND TOILET BUILDINGS.





PLAN

KNOCKDOWN PORTABLE CAMP—TYPICAL PLAN FOR COMMISSARY STOREHOUSE

Appendix C.

SUBJECT:

(4) The study of the matter of establishing proper relations between the unit of track expenditure and the unit per mile of line for different classes of roads for the purpose of determining a normal maintenance expense, and to obtain, as far as possible, uniform conditions involving—

"a"—Separation of expense as between Road, Bridge and Building and Signal Departments.

"b"—The determination of the ratio of labor cost to total cost.

H. R. SAFFORD, *Chairman;*
A. C. MACKENZIE,
W. A. JAMES,
R. C. FALCONER,
J. Q. BARLOW,
C. B. HOYT,

Sub-Committee.

Committee reports progress for the current year.

This subject is one of wide scope, and the development of it as related to an individual line embraces many local problems which differ in character as between roads, and the Committee can only hope to develop an outline of general principles.

Regardless of how definite and complete the policy of maintenance may be on an individual railroad, there must be in the development of this policy a clear perspective of the general relations between expenditures on different classes of line and between the major sub-departments to guard against distorted and inconsistent proportions.

The necessity for a study of this kind is increasing rapidly, because standards of maintenance are constantly being more closely scrutinized and made the subject of discussion, and in the development of the entire railway problem this is getting to be a more and more important feature.

One of the roads represented on the Committee has attempted a study of this subject as related to its own zone, and the Sub-Committee presents an abstract of the results of that study, which, of course, is submitted only as information.

Two statements are attached hereto and identified as Exhibits "A" and "B."

Exhibit "A" is an analysis of relative expenditures of departments for the three year period from 1915 to 1917, inclusive.

Exhibit "B" is an analysis reflecting for the same period certain units of expense determined, first, by classifying the road into four general classes, and, second, equating the various classes of tracks to a standard of one mile of main track.

By reference to Exhibit "A" it will be noted:

(1) The ratio of road department expense to total maintenance of way expense varied from 76 per cent. to 79.2 per cent.

(2) The ratio of Bridge and Building expense to total maintenance of way expense varied from 18.2 per cent. to 22.5 per cent.

(3) The ratio of Signal expense to total maintenance of way expense varied from 1.5 per cent. to 2.6 per cent.

(4) The ratio of Road Department labor to total labor expense varied from 77.9 per cent. to 79.1 per cent.

(5) The ratio of Bridge and Building Department labor to total labor varied from 18.5 per cent. to 19.8 per cent.

(6) The ratio of Signal Department labor to total labor varied from 2.2 per cent. to 3.5 per cent.

(7) The ratio of Road Department labor to total Road Department expense varied from 54 per cent. to 54.8 per cent.

(8) The ratio of Bridge and Building Department labor to total Bridge and Building Department expense varied from 46.8 per cent. to 56.2 per cent.

(9) The ratio of Signal Department labor to total Signal Department expense varied from 68.2 per cent. to 74.5 per cent.

These ratios, of course, are without regard to classification of line, and the figures cover the system as a whole.

The analysis extended over the three-year period above mentioned, during which time important and erratic increases occurred in the cost of labor and materials, and yet it is interesting to note that the relative percentages were not changed materially thereby.

Labor, of course, is the basis for all material costs, and if labor in all classes of industrial development increases in about the same ratio, and if a normal program of work is maintained, it follows that the proportions should not differ materially, but it was somewhat surprising that during the period under discussion, with all of the violent fluctuations in material costs, that these relations were not vitally affected.

Of course, during the year 1918 it is quite probable that a similar analysis would establish different proportions as between labor cost and material cost because of the rather heavy increases put in effect during the year in railway service, and yet it may be found that material costs followed about the same curve.

Exhibit "B."—This analysis reflects a suggested method for attempting to establish a normal maintenance cost, having regard to two major conditions—first, class of road, and second, equated track units—the basic unit being one mile of main track of first-class railroad.

The railroad under consideration occupies a northern latitude and is subject to extremes of climate ranging from twenty degrees below zero to one hundred degrees above zero, and embraces a mileage of about one thousand miles, which were divided into four classes, as follows:

Class A-1. Being a double track, heavy traffic density line on which the standard of maintenance provided for the laying of 100-lb. rail, and carrying a high speed passenger traffic and a

heavy freight traffic with locomotives equivalent approximately to Cooper's E-50 loading.

Class A. Single track line handling similar traffic, except passenger train service was local, but engine loadings were the same. The standard of maintenance on this class of line called for the use of 90-lb. rail.

Class B. Medium light branch line, well ballasted and laid with relaying rail, and handling locomotives equivalent to about E-40.

Class C. Very light branch lines handling a limited traffic, not exceeding three or four passenger trains and three or four freight trains per day.

Certain assumptions had to be made for the purpose of equating track values, which were as follows:

$$\text{One mile of main track is equivalent to} \begin{cases} \text{2 miles of passing track,} \\ \text{2}\tfrac{1}{2}\text{ miles sidetrack,} \\ \text{15 switches.} \end{cases}$$

In this analysis the period under consideration was five years from 1912 to 1917, inclusive, during which period costs generally increased, but fairly stable proportions were maintained throughout the period.

Of course, this analysis does not cover other important features of the work, such as Bridges and Buildings, Signals, etc., but any study of this kind necessarily must be progressive, and track expenditure being the larger proportion of total expenditure, logically should be taken first.

In conclusion, the Committee urges and recommends the continuation of this study leading to further and important results.

Exhibit "A."

Table 1.

ANALYSIS OF EXPENDITURES OF ROAD, BRIDGE AND BUILDING AND SIGNAL DEPARTMENT

1. TOTAL EXPENDITURES OF DEPARTMENTS (Exclusive of Superintendence)

	1915	%	1916	%	1917	%
Road Department	$4,786,652	79.2	$5,067,423	76.0	$6,614,121	79.6
B. and B. Department	1,100,227	18.2	1,505,770	22.5	1,547,161	18.6
Signal Department	157,251	2.6	121,567	1.5	140,463	1.8
Total	$6,044,130	100	$6,694,760	100	$8,301,745	100

2. EXPENDITURES FOR LABOR ONLY

	1915	%	1916	%	1917	%
Road Department	$2,580,261	78.0	$2,767,298	77.9	$3,622,909	79.1
B. and B. Department	619,590	18.5	704,006	19.8	856,958	18.7
Signal Department	117,302	3.5	83,074	2.3	101,534	2.2
Total	$3,317,513	100	$3,555,378	100	$4,581,491	100

3. RATIOS OF LABOR TO TOTAL EXPENDITURE (Based on 1 and 2)

	1915	1916	1917	Average
Road Department	54.0%	54.6%	54.8%	54.5%
B. and B. Department	56.2%	46.8%	55.5%	52.8%
Signal Department	74.5%	68.2%	72.2%	71.6%
All Departments	55.1%	53.1%	55.1%	54.4%

It is evident that the labor factor—or ratio of labor to total expenditure—of the Road Department and Maintenance Department as a whole, has remained constant, regardless of increased costs of both labor and material.

The increase in average cost of material is affected by variations in the maintenance program, and can be determined approximately from data available for the Road Department only.

Since Road Department labor and material represent nearly 80 per cent. of the total expenditure, the ratios and rates of increase in that department—as determined in the attached analysis—are reasonably satisfactory for general application.

ANALYSIS OF EXPENDITURES OF ROAD DEPARTMENT LABOR COSTS ARE EXCLUSIVE OF SUPERINTENDENCE

ROAD DEPT.	1915		1916			1917			
	Amount	%	Amount	%	Increase Over 1915		%	Inc. Over 1916	Inc. Over 1915
LABOR..........	$25806.21	54	$27672.98	54.6	7.1%	$36229.99	54.8	31%	40.5%
MATERIAL.....	22060.31	46	23001.25	45.4	4.5%	29911.22	45.2	30	36
	$47866.52	100	$50674.23	100	6.0	$66141.21		30.5	38.5%

	1915	1916	1917
Rates of Pay	Foremen $2.40–3.55 Men $1.70–1.80	Net increase in rates of "regular men" } 4% i. e.—Account new schedule in effect after September 1st, or ⅓ of year. Foreman $2.60–3.75 wgt. average men $1.95–2.05 inc. 12.5%	Net increase to regular men { over 1915 12.5%, over 1916 8.5% For reason shown opposite.
Total Increase for Labor.		4% due increased rates of regulars. 3.1% due extra gangs at higher rates. 7.1% total increase (as above).	over 1915 } 12.5% due increased rates of regulars. 28.0% due extra gangs at higher rates. 40.5% total as above. over 1916 } 8.5% and 22.5% respectively.

MATERIAL	1915	1916	1917
New Rail.	60 Miles	133 Miles	105 Miles
Ballast.	175 Miles	196 Miles	263 Miles
Frogs and Switches	2228 Miles	2258 Miles	2057 Miles
Cross-Ties.	1,900,000	1,485,000	1,735,000
Inc. over 1915.	Rail Ballast Frogs Ties	73 Mi. @ $3000 = + $219,000 21 Mi. @ 500 = + 10,500 30 mi. @ 400 = + 12,000 415000 0.60 = − 249,000 Net = − $9,000 practically equivalent to 1915.	45 Mi. @ $3000 = + $135,000 88 Mi. @ 500 = + 44,000 170 Mi. @ 400 = − 68,000 1650000 0.60 = − 100,000 Net = + $11,000 practically equivalent to 1915 and similarly it may be shown to be about same as 1916.

The above prices are approximate for 1915 and are applied merely as a rough check of the relative amounts of material used each year, and it is therefore evident that had 1915 prices prevailed the total costs of material would have remained practically constant.

Since the "equivalent quantities" of material are practically constant for these years, it is fair to assume that the weighted "Average Cost" of

Road Department materials has increased in the same proportions as the total expenditures for material, as shown above.

This assumption would be absolutely correct for roads with definite maintenance program, i. e., fixed per cent. of tie renewals, fixed life of rails, etc.

Ratio of Labor to Total Cost	54.0%	54.6%	54.8%	Authorised increase in rates less than total increase in labor cost—due to extra gangs or extra men substituting for regulars of higher than scheduled rates.
Authorised increase rates of labor over 1915		4.0%	12.5%	
Authorised increase rates of labor over 1916			8.5%	
Increase weighted average cost Material 1915		4.5%	3.6%	
Increase weighted average cost Material 1916			3.0%	
Total cost of labor increase over 1915		7.1%	40.5%	
Total cost of labor increase over 1916			31.0%	

Exhibit "B."

Table No. 2.

AN ANALYSIS OF THE COST OF MAINTENANCE OF WAY AND STRUCTURES FOR THE PURPOSE OF ESTABLISHING PROPER RELATIONS BETWEEN EXPENDITURES PER MILE OF LINE AND UNIT OF TRACK FOR DIFFERENT CLASSES OF ROAD.

Class	Average Annual Exp. M. W. & S. Five Years	Line	Miles: Main Track	Miles: Other Track	Total Track	Equated Track Miles
A-1	$910,000	347.0	674.9	174.0	848.9	790.9
A	402,000	190.5	206.1	136.1	342.2	296.9
A	306,600	165.2	166.2	85.4	251.6	223.0
B	73,360	54.2	54.2	35.2	89.4	78.6
C	74,000	100.6	100.6	11.0	112.5	108.5
C	64,200	105.6	105.6	15.3	120.9	115.8

Equated track values—Assume 1.0 mile main track—1.5 miles siding, including switches.

Since "miles of track" per mile of line will vary on different divisions, it is desirable that separate units be determined for miles of line and units of track and an analysis of the maintenance of way structures. Accounts for the above lines indicate that about 60 per cent. of the total expense is affected by trackage and about 40 per cent. of the total expense is affected by miles of line (reflecting buildings, fences, etc.).

When unit costs are—

Class	MILE OF LINE BASIS PLUS MILE OF TRACK (equated) BASIS					
	40% of Total M. W. & S. E.	Miles of Line	Per Mile Line	60% of Total M. W. & S. Exp.	Equated Track Mi.	Per Mi. Track (Equated)
A-1	$364,000	347.0	$1050	$546,000	790.9	$690
A	160,800	190.5	845	241,200	296.9	814
A	122,640	165.2	745	183,960	223.0	825
B	29,344	54.2	543	44,016	78.6	565
C	29,600	100.6	296	44,400	108.5	409
C	25,680	105.6	246	38,520	115.8	336

That is

COST OF MAINTENANCE	PER MILE OF		Factors (See Note)	
	Line	Track (Equated)	Line	Tackage
Double Track, Class A-1............	$1050	690	1.00	0.66
Single Track, Class A..............	800	820	0 76	0.78
Single Track, Class B..............	540	560	0.51	0.53
Single Track, Class C..............	275	375	0.26	0.36

"Factors" are relations between cost of any unit and 1 mile of line of double track, Class A.

Having established "factors" as above, it is possible to reduce all "maintenance units" to a common basis and thus determine the proper distribution of the allowance for maintenance as between various divisions or districts, as, for example:

Territory	Miles of Line Class				Miles Track			MAINTENANCE UNITS		
	A-1	A	B	C	Main	Other	Equated	Line	Trackage	Total
1st Dist.....	100				200	66	244	100x1.00=1.00	244x0.66=161	
2d Dist.....			50		50	22	72	50x0.51= 26	72x0.53= 37	
"A" Div....	100		50		250	99	316	1.26	198	324
3d Dist.....		90			90	26	114	90x0.76= 68	114x0.78= 89	
4th Dist.....			200		200	90	260	200x0.51=102	260x0.53=138	
5th Dist.....	50				100	48	132	50x1.00= 50	132x0.66= 87	
"B" Div....	50	90	200		390	174	532	220	314	534

That is, "A" division, with 150 miles of line and 250 plus 99=349 miles track, has 324 maintenance units.

"B" division, with 340 miles of line and 390 plus 174=564 miles track, has 534 maintenance units.

Then if maintenance is to be normal (i. e., about same as average for past years), "A" division should have 324 × $1,050, or $340,200; "B" division should have 534 × $1,050, or $560,700.

In a similar manner, the total maintenance allowance may be fixed for any particular district, though, of course, it may be desirable to modify the "factors" somewhat to allow for any unusual conditions existing there—such as a large number of timber structures, etc.

Having determined the total allowance, it is possible by similar methods to arrive at the distribution as between different departments, and further as between labor and material for each department.

Appendix D.

(5) LABOR-SAVING DEVICES.

C. H. STEIN, *Chairman;*
R. C. FALCONER,
J. W. PFAU,
W. J. BACKES,
A. F. BLAESS,
LIEUT.-COL. H. J. SLIFER,
Sub-Committee.

(5) Your Committee reports progress and asks to be relieved from further investigation of this subject. The field has been as thoroughly canvassed as possible during the past two years, and the Committee presents herewith a list of 30 well-known and efficient labor-saving devices in use on railroads, and 35 "kinks" or labor-saving devices used not so generally and little known, but of marked utility as railroad specialties.

MANUFACTURED OR PATENTED DEVICES.

1. Thawing Machines.

Various appliances for use in removing ice and snow from interlocking switches, frogs and derails; for thawing frozen bearings of cars, thawing frozen water pipes and burning weeds. These devices consist of different styles of blow torches or flame throwers with the necessary containers and power.

2. Hydro-Carbon Snow Melting Process.

This is a process whereby the by-product obtained from the manufacture of Pintsch gas is utilized with specially designed and patented safety cans to distribute oil over frogs, switches, interlocking pipes, etc., for the purpose of removing snow. It is in use on a large number of railroads. Each can holds approximately three and one-half (3½) gallons of oil and can be operated by one man. The outlet consists of a safety cap and valve, the latter being opened when the point is reached where it is desired to distribute the oil. After the valve is open the oil begins to flow and is lighted by a match or torch and the ignited oil, as it issues from the can, remains burning on the snow until the snow is melted. Some roads have used, instead of the hydro-carbon oil obtained from the Pintsch gas, a specially prepared oil manufactured for the purpose. There are various other devices and appliances of a similar character on the market.

3. Portable Milling Machine for Milling Pockets in Stock Rails for Switch Points.

This device can be clamped to the head of the stock rail and operated by hand, so that the pocket to the switch point can be milled from the stock rail without the necessity of taking the rail from the track. It is said that the milling of the stock rail for the switch point will result in less wear on the switch point, with consequent longer service.

4. Pneumatic Tie Tamper.

This is a pneumatic device consisting of a pneumatic hammer with tamping iron attached and an air compressor car. It is used for tamping

all kinds of ballast and is considered a very economic device with certain conditions. It is claimed to be particularly useful around frogs, switches, crossovers, water pans, and other places that are inaccessible to the ordinary tamping pick and bars. It is in use in large numbers on many of the railroads.

5. Side Dump Cars.

These are manufactured by a number of concerns and are very popular. They are operated in trains just as the ordinary freight car is handled and are unloaded either by hand or pneumatically; or, if small, can be set in pairs on top of ordinary flats.

6. Spreader Cars.

There are several designs of this device on the market. They generally consist of an all-steel, air-operated, double-wing car used for levelling earth and plowing snow. One man is employed to operate the machine and it is controlled entirely by air from the locomotive. It is estimated that this machine will perform the work of an equivalent of 300 men, where there is use for it. It is stated that on one division of a Western railroad it was used during the entire winter of 1917 for handling snow.

7. Rail Unloaders.

There are several designs of this machine. It is a small derrick mounted on wheels and may be moved over the tops of gondola cars and raised on their sides for loading and unloading rail. It is also built on an ordinary flat car, operated by air from the train line.

8. Railroad Motor Inspection and Section Cars.

These are manufactured and sold by various large concerns, are built along the same general lines, and are direct or indirect connected drive. Each manufacturer employs certain specific principles of design that are peculiar to his car. Those who have made tests of these cars, as compared with the old style hand-operated car, claim that there is tremendous economy in their use.

9. Air Motors.

These are commonly known machines and are manufactured by many concerns producing air appliances. They are used to operate rail drills and wood mortising machines, rail saws and any power-driven machinery.

10. Electric Motors.

These perform the same class of service that air motors perform and are sold by all of the large manufacturing establishments.

11. Oxy-Acetylene Welding and Cutting Apparatus.

This is a portable welding and cutting unit mounted on hand truck, the gas being secured from acetylene and high pressure oxygen cylinders, and is of tremendous utility, especially on a wreck train, where it can be used for cutting apart couplers and all classes of steel, thus materially

reducing the time consumed in doing the same class of work by hand. It is also used for repairing worn-out frogs and for cutting rails and bridge steel.

13. Stone Ballast Screen Cleaner.

This is a device similar to any ordinary screen with a bag attachment into which the dirt falls. This screen is so designed that it can be placed between tracks and afford clearance. It is highly recommended by some users.

14. Conveyors.

These are known as wagon loaders and are produced by conveyor machinery manufacturers. They are made portable for handling material such as sand, crushed stone and coal.

15. Three-Man Track Layer.

Under certain conditions of track laying it is said that very considerable savings can be made by using this machine, which is of the portable derrick variety, suitable for handling single track rails to place.

16. Weed Killers or Destroyers.

These devices are of different varieties; one where the weeds are destroyed by a chemical solution fed upon the track and to a certain distance outside of the rail by a sprayer car; another destroys the weeds by superheated steam without the use of chemicals. It is estimated that where there is use for devices of this kind, the cost per mile of track is but a small percentage of the cost of removing the weeds by the old method of hand labor.

17. Ditching Cars.

Small cars on narrow-gage tracks into which ditch cleanings and other refuse material may be loaded and pushed by hand to nearby disposal grounds. The small bodies of these cars set in trunnions and can be turned over by hand to unload with very little effort. The narrow gage track is constructed alongside and clear of the running track wherever the space is sufficient.

18. Locomotive Cranes.

These devices are of standard make and are manufactured by a number of large concerns, and of various capacities. Their utility for various purposes is well known. They are manufactured with long and short booms and can be used for handling all kinds of material, and for excavating by use of clam shell pockets; also for light ditching around coal yards. They are made self-propelled and non-self-propelled. Many of them are also made with pile-driving attachments. They have the advantage that one is able to place them in almost any location where a car can be placed. The locomotive crane has a wide field of utility and is perhaps one of the most economic and useful machines on a railroad. Cuts are herewith submitted showing some of the uses to which they can be applied.

19. Portable Air Compressors.

These machines are manufactured by almost all concerns manufacturing pneumatic tools and can be used to produce power wherever air tools are used; that is, for hammers, riveters, chippers, drills; for mortisers and other wood-drawing tools. The Pneumatic Tie Tamper, referred to above, uses a portable compressor car in connection with its operations, which, unlike the ordinary air compressor, is attached to a standard gage car.

20. Printing Press.

These devices are hand-lever presses with platen rollers. They are used for printing titles on drawings with special ink, save labor and hand-lettering and keep standard form of titles on all tracings and maps. They are also used for envelope headings, titles on filings jackets and other small printing jobs and are very useful in the general offices of railroads.

21. Excavating Rails.

It is said that this device was in use on a certain large railroad as far back as the year 1900, but it is now patented and consists of two short rails laid parallel to running rails. The running rails are supported on stirrups hung from the short rails. Its use is to carry any track under traffic while excavating beneath the same for sewer, water pipes, etc. It is a cheap arrangement and is a good and economical substitute for the old method of digging out under the track in order to place wooden stringers.

22. Woodworking Machine.

This machine consists of a saw table, shaper, band saw, jointer, mortiser and planer. It is operated by a 7½ H.P., 3-phase, 60-cycle, 220-volt electric motor, belt driven. It is used for making and repairing furniture, manufacture of screens, screen doors, storm doors, windows and every description of light mill work, common to railroad terminal shops and offices.

23. Concrete Mixer.

These machines are of various designs and types, are portable and sometimes placed in a stationary position on flat cars. They are produced by a large number of manufacturers and are economical substitutes for the old hand method of mixing.

24. Blue Printing Machine.

A number of modern machines have been produced by various manufacturers combining printing, washing and drying features; also automatic rolling-up device operated by motor. These are very useful and economical as compared with the old hand method of blue printing.

25. Portable Trench Pump.

This is a gasoline-driven pump mounted on truck complete with engine and side suction open side discharge pump of the diaphragm type. It is useful around all bridge construction and sub-structures where water

is encountered, where a large pump is not necessary and where hand pumping involves a large amount of labor.

26. Railroad Ditcher.

The ditching machine is a popular modern device for excavating from the decks of flat car trains or from the ground. The railroad ditcher is a labor saver and is put to a variety of uses. It is sold with a pile-driving attachment, and has been used to handle a clam shell and to perform other work usually done with a locomotive crane. The ditching machine has the advantage of being readily portable and quicker in action than the heavier steam shovels or cranes.

29. Switch Point Straightener.

This consists of a clamp or vice arrangement with ratchet rising bar for lever. One man can straighten switch points without removing points from track. It is applied to the switch point in about the same way as a rail bender is used.

30. Rail Joint Expander.

This device fits from 50 to 100-lb. rail. Its purpose is to get expansion for end posts when installing insulated joints for track circuits. Clamps are attached to ends of each rail or joint and screw jack arrangement between clamp is operated with small bar or jack lever. It is said that it can be handled by two men and takes place of six or eight men to drive rails for expansion.

Special Devices or "Kinks."

1. Roadbed Cultivator.

This is an implement for economically and efficiently plowing up ballast which has settled or become impregnated with growth of weeds; and reshaping of the ballast to standard contour. The equipment is mounted upon a car specially designed for the purpose and consists of a pair of plows with a scraper or ballast spreader located to the rear of the plows.

The raising and lowering of the plows and shaper is done by air pressure and can be entirely controlled by two men.

The plow next to the rail is placed forward and above the outer plow. The forward plow cuts a furrow in the roadbed adjacent to the ends of the ties, the bottom of this furrow being slightly below the level of the bottoms of the ties. The gravel or other material of the roadbed is thus thrown by the plow inwardly toward the rail and up onto the ends of the ties. The gravel at this point, that is, adjacent to the ends of the ties, is usually finer than that further down the slope of the roadbed, and it is the function of the forward plow to remove this relatively fine gravel from the upper part of the roadbed and pile it temporarily on the ends of the ties.

The plow following below and outside of the first plow throws the relatively coarse gravel of the lower portion of the slope of the roadbed up into the furrow made by the first plow, the bottom of which furrow,

as before stated, is slightly below the level of the bottom of the ties. Thus free drainage is provided for that portion of the roadbed immediately below the ties.

The horizontal scraper following the plows is adjusted to clear the tops of the tie ends, the forward end thereof running parallel and adjacent to the rail. The inclined portion of the scraper scrapes the relatively fine gravel which has been thrown up onto the tie ends by the first plow off of the tie ends and over the edge of the roadbed, whereupon this gravel falls down into the lower furrow made by the second plow. Thus by the co-operative action of the two plows and the scraper, the relatively coarse gravel at the lower edge of the slope of the edge of the roadbed and the relatively fine gravel at the upper part thereof are made to change places. The scraper or spreader smoothes out any inequality in the slope of the roadbed left by the plows and forms slope to the desired contour.

Inasmuch as similar members are mounted on both sides of the cars, but controlled by separate mechanisms, the two sides of the roadbed may or may not be treated simultaneously as convenience or necessity may direct. Means are provided to permit operation of the cultivator over irregularities in the roadbed, on curves, where the outside rail is raised and where obstructions are encountered. Not only can the plows and scrapers be raised up to a vertical position to clear obstructions, but they may also be swung back or in towards the side of the car.

The cost of operation of the roadbed cultivator per mile of track varies considerably according to obstructions encountered, as well as density of traffic, but considerable of the work has been done at a cost as low as $1.30 per mile. This cost includes engine service, wages of train and engine crew, as well as wages of operators on the cultivator.

2. Light Derrick.

A light derrick, handling 3,000-lb. loads, that can be quickly mounted on an ordinary push car, has been found to be a great labor saver in bridge gangs.

3. Tie Plate Elevator.

The tie plate elevator consists of a link belt conveyor upon which tie plates are received after leaving the punching machine. Through means of the link conveyor, plates are elevated to a sufficient height and discharged upon an inclined plane which is swung over the track in such manner as may be desired to discharge plates directly into gondola or other type of car spotted for loading. The machine is rendering very efficient service.

4. Oil Sprinkling Device.

This attachment consists of a perforated 2½-in. black iron pipe, coupled to the discharge openings of a standard oil tank car. The method of regulating flow of the oil, as well as raising and lowering the pipes to avoid obstruction while in motion, is illustrated on drawing attached.

Perforations in pipe consist of ½-in. holes placed 2 in. center and

threaded for plugs. Plugs are used in the alternate holes when the oil is hot and running freely. In cold weather plugs are removed in order to secure proper flow of oil. The swing joints in the pipe consist of ordinary elbows with a nipple between them.

5. Straddle Leg Pile Driver.

The trestle across Great Salt Lake is 12 miles long, with very heavy traffic, and piles cannot be driven with an ordinary car pile driver without great delay to trains and heavy expense for work trains.

The use of floating pile drivers cannot be resorted to an account of the roughness of the lake.

Photograph submitted shows an adaptation of an ordinary straddle leg bridge traveler to pile driving purposes; the driver moves on rollers on the outer edges of the deck, the engines being placed on the upper platform and leads are pivoted so as to swing in either direction. The trestle is of the ballasted deck type and is 16 feet wide. The driver is 14 feet 8 inches wide and 22 feet high in the clear, making it possible for trains to operate through it without interfering with the driving.

6. Tie Plug Machine.

In years past it has been customary for section men to make tie plugs from straight grain redwood ties. Plugs were sawed four inches in length and split with a hatchet as near as possible to size. Average output per man per day was 1,000 plugs.

Several types of machines were devised for sawing and sizing plugs. A machine was finally perfected with an output of 100,000 plugs per day at a cost of 55c per thousand.

Mr. Carman recently designed and has obtained U. S. Letters Patent, No. 1,218,836, on an improved type of tie plug machine, which will have an average output of 400,000 tie plugs per day, at a cost ranging from 26c to 40c per thousand, according to the price of the lumber from which the plugs are manufactured.

Prior to the advent of the new machine, mill-sawed timber was used in the manufacture of the tie plugs, whereas the new machine will turn out the plugs from timber as it comes from the forest and will work up refuse lumber about the lumber mills.

It is preferable to locate the machine and manufacture the tie plugs at mills where the timber is handled.

7. Weed Burner.

The weed burner is constructed on a car 52 feet in length, the body of which is made from scrap steel bridge girders. Car carries a burning table, lined with fire brick, with a movable wing on each side of the table to extend out over and down the shoulder of the bank for the purpose of directing the flames onto the outer slope of the bank. The burning table, as well as the wings, are raised and lowered by air pressure. Valves covering the operation of the burning table and wings are centrally located, making it possible for one man to readily control the burning operation.

Distillate is used for fuel and is sprayed with steam pressure supplied from the locomotive.

The implement was designed for the purpose of burning grass and weeds upon the track and the best results are obtained in the early spring while the grass is yet green, the object being to sear the growth and kill the root. As a general rule, two burnings are required for good results; the second burning following the first by an interval of a few days. Where the weed growth is very light or quite dry, one burning may be found sufficient. In order to keep the roadbed entirely free from weeds, some supplemental hand work usually has to be done where the growth is unusually heavy or where certain patches of perennial vegetation may occur; but, on the whole, it is considered an economical operation, as compared with depending upon hand labor, even in normal times, and all the more so under prevailing conditions.

The average cost, all items of expense included, for first burning has been approximately $10.00 per mile and for the second burning $6.00 per mile, or a total of $16.00 per mile where first and second burnings have been made.

9. Extension Beam.

For the convenience of jacking up derailed locomotives. This device consists of four steel plates 6 feet long with 3-inch holes placed every 12 inches to receive a pin of the same diameter, which engages the underside of the pilot beam and the top face of a 12 x 12 x 18 ft. timber which extends a sufficient distance outside of the track and affords a purchase high enough to secure adequate foundation for jacks without the usual excavation. In practice, the device has proven most successful and eliminates considerable lost time in re-railing of locomotives and consequent damage to track where practice of pulling them is applied.

10. Frog Wing Bender and Templet.

This tool consists of ordinary switch tie for a foundation, around which is fastened a "U" strap, which is drilled near the end of arms to receive a 2½-inch pin which engages the wing rail to be bent. An ordinary track jack being applied at one end after proper heating; templet being made of gas pipe as an adjustable middle arm and when adjusted to the old wing will produce the same angle when placed in the same relative position on the rail to be shaped. In practice it has been found possible to heat and bend a rail to the desired angle in ten minutes, which is about 10 per cent. of the time ordinarily required where hammer and angle is used and a more satisfactory job is obtained. The same tool is also used for making short breaks of rail in maintenance of way shop.

13. Power Rail Curver.

This device consists of old style Elliott stationary roller bender anchored to a dead-man in a vertical position, the rail being passed to the rollers in the usual manner, the movable part tightened and power applied either by locomotive or stationary engine and rail drawn through,

against the usual practice of a socket wrench and hand power. In this manner 125 rails per ten-hour day may be curved to the desired radius with eight men and an engineer. This machine is used to curve lead and curve rails and for straightening of damaged rails and curving of guard rails. Surface rails are also straightened by reversing the position of the rail in the roller.

14. Screw Spike Remover.

This device consists of attaching a large wheel to a screw spike wrench in place of the ordinary T-handle. It is noticeable that in removing screw spikes, two men are required and the constant changing of hands on the ordinary T-handle makes the process slow and awkward. If a large wheel, of the old heavy type of a brake wheel with a handle attached to its side, is used, the momentum of the wheel held by one man and revolved by the handle by the other without removing his hand, will quickly remove a spike from a tie.

15. Erection and Repairs of Water Columns or Removal.

This kink consists of a collapsible A-frame made of 2-inch and 2½-inch pipe and guyed two ways with a 1-inch rope, to carry the overhead blocking necessary to hoist the parts in place. Ordinarily a long wooden tripod is used for erecting any part of the crane and setting this up requires at least four men. The length of these legs is 22 feet. If the crane is in an isolated place and is an important water station, it is expedient that the new parts and the tools for replacing them be hurried along by passenger train. With two such collapsible legs made up of a 12-foot length of 2½-inch pipe with 12-foot extension of 2-inch pipe and enough tackle and rope to guy the frames both ways, two men can handle any part, and easily place it in the baggage car of the train.

16. Shackle Band for Repairing Timber Trestles.

This is a device used on timber trestles where caps are in need of renewing or the stringers need shimming on account of the settling of the bents. A shackle band is made of 1-inch x 4-inch iron bent so as to fit over an upright post of the bent itself.

Another shackle band is made to fit inside the first and held there by a 1-inch bolt. The back of the smaller band is sharpened somewhat in forging, so that it will grip the 12-inch timber as soon as any weight is put on it.

The bolt is removed when the device is to be used, the larger band slipped around the 12-inch x 12-inch and the inner band put in place. It can be put around the bottom of a 12 x 12 post and two men can raise it to the required height. After the weight of the larger band is taken by the sharp edge of the smaller it grips the timber and the grip increases with the weight put on it. Two such bands will make a scaffold that will raise any set of stringers. If a joint comes over the bent, all that is necessary is to chain both sides of the rail and lift rail and all. Then the bent is free to take off the cap or even replace one of the posts if necessary.

17. Oil Sprayer, for Spraying Rail and Fastenings.

This machine is used for spraying rail and fastenings with oil. Its purpose is to spray such fastenings with oil in order to prevent corrosion and to enable the fastenings to be taken off and replaced readily without destroying any of the parts, as so often happens when they become corroded.

18. Tie Spacers.

This device is clamped to the base of rail and used for a fulcrum of a spacing bar, for spacing ties, and is in general use on one of the large roads. It is said to be simple and easily handled, and eliminates the damage ordinarily done to ties by pounding them to place with a spike maul.

19. Rail Unloader.

This consists of an apron and hook for unloading rail endwise from flat cars. A chain is used with hook on one end and a bolt that can be put through a hole in the rail at the other end.

The hook is set over the end of a splice in the track and as the car is moved slowly forward the rail is unloaded, and the sloping pieces of the apron guide the rail to the side of the track outside of the track rail.

20. Track Liner.

This device is a wedge-shaped wooden block, 18 inches long, 8 inches wide and 2 to 5 inches thick, cut out of a tie or piece of 5-inch crossing plank and put under the rail, the 8-inch x 18-inch base of the block being set horizontally. The claw bar is then put under the rail and by pressing down towards the ground on this claw bar it is said one can do as much lining with three men as can be done with six men prying up on lining bars. A 2-inch diamater pipe 5 feet long is attached to the end of the claw bar to give the men leverage. The ballast is moved from the ends of the ties and dug out between ties about down to the bed or base of the ties, so that the block may be put in and so that the claw bar will fit snugly between the base of the rail and the block. The men then put the pipe on the claw bar and put it in place, prying down on the claw bar; this kicks the track over to line. It is particularly useful in cinder ballast. It is also said to be used to good advantage on slips, which in the winter time have to be lined very frequently. It is said that during last winter on a five-mile section, containing about 1½ miles of slipping track, a foreman with only two men was able to keep this track in line. In soft weather, where this track had to be lined almost every other day, for from two to four inches, the foreman did all of his lining with this block and claw bar.

24. Tie Plug Driving Device.

This device is similar to a concrete tamper, with a large, flat head, for driving tie plugs while in standing position, which makes the driving much easier and much quicker.

25. Rail Roller.

This is a simple roller device used for the driving rail where it is

necessary to space rail or open up joints, and is a substitute for the ordinary method of lifting the bumping rail with tongs and sliding it over angle bars.

26. Machine for Replacing Bridge Ties.

This device consists of a horizontal 20-foot wood boom set in a steel underframe, on which is mounted a windlass operating grab hooks by means of a system of cables and pulleys, the whole machine resting across a push car above the ties to be replaced.

The base is an 8-inch channel iron 12 feet long, on each end of which is erected a ¾-inch x 4-inch stirrup or U-shaped iron, riveted through the bottom of the channel. Between the uprights of this stirrup are two rollers 6 inches in diameter placed about 6 inches apart. Between these rollers is a wooden boom 5 inches x 6 inches x 19.6 ft., with a four-inch sheave in each end, over which a ⅜-inch wire cable runs to two small flanged pulleys 4 inches in diameter with cranks attached. This is for hoisting or lowering the ties. These pulleys have notched edges on one side in which a dog engages to hold the tie at desired height. There is a pulley on the channel iron shown just at the edge of push car. This has ¼-inch wire cable two turns around and locking, and is used to extend or draw in the boom. There are grab hooks on end of cable for fastening to ties. The machine is also supplied with anchors from end of channel iron which hooks under guard rails. It is only necessary to use this when removing or replacing caps to keep machine from tipping over.

In replacing ties, the old tie coming out balances the new one being put in and anchors are not required. In replacing ties small quick-lifting jacks are used, set on the stringers between the ties and raise ties clear of the stringers about 2 inches.

It is said that this avoids the necessity of removing guard rails, and that eighty ties have been placed with it by six men in one day. The push car is equipped with a plate fastened to deck of car, through which a king bolt is inserted, thus allowing it to be swung at an angle. It can be lifted off the car readily.

27. Machine for Transferring Coal from Crippled Cars.

This is made of old material and, it is said, will transfer a fifty-ton car in one hour with two men, if the car is self-cleaning.

28. Holder for Head of Bolts in Keystone Insulated Joints.

This device is used when tightening nuts to prevent bolts turning. The tightening of nuts on bolts of Keystone insulated joints is very difficult for one man to handle. It often happens, therefore, that they are neglected. The device shown in sketch holds the head of the bolt so that the bolt will not turn and may be tightened with one wrench.

29. Painting of Signs with Raised Letters.

The practice which is here suggested has been used with very good results, is to take a piece of plush drawn tightly over block of wood 2 x 3 x ⅞ inches and tack the plush to the edges. Paint should be thick

and applied to plush pad with a brush. The pad should then be rubbed over the face of the letters very lightly. This practice has been used for a number of years, and it is found that on signs with a great deal of lettering as much work can be done in five minutes with this device as with a paint brush in from two to three hours. Furthermore, the work has been found to be durable.

30. Staggered Switch Points.

Wear on switch points and the possibility of derailments where switches depart from the inside of curves has been a very serious matter. To overcome this, certain roads have staggered their switch points by placing the one switch point 2 feet ahead of the other, in order to be able to place a guard rail opposite the switch point on the high side of the curve and thus relieve the wear and tear and strain against that point. This is particularly useful in yards and is not recommended for high speed main track use. The cut will show method of installation.

31. Foot Rest for Shovel.

This consists of a piece of gas pipe 3 inches long split and fastened to a tamping shovel to serve as a foot rest. In some instances a light piece of angle iron is used instead of gas pipe and riveted to the shovel. The gas pipe, however, has the advantage of curvature and is easier as a foot rest for the shoveller. This is said to give good results as a labor saver.

32. Lining Bar Plate.

This is said to effect a saving of about 50 per cent. in the labor of actual throwing when track is lined. The device consists of a steel plate ½ x 5 x 15 inches. When in use it is laid on the ballast under the rail, and makes a firm support for the point of the bar, preventing slipping and increasing the leverage of the bar. It is said that by the use of this device a smaller gang can line track than otherwise.

33. Cultivator Disc for Cutting Sod Lines.

This cultivator disc on an adjustable rod is fastened to a push car or hand car. It has been found effective in cutting sod lines and is much faster than the ordinary method. It is said to make a line which looks well and approximates the standard in distance from the track.

34. Rail Loader.

This machine is used where a regular loading machine or derrick car is not available. It is said to be very effective in picking up and loading rail along the tracks. It consists of a piece of wire cable about 100 feet long; on one end there is a grab hook made from the jaws of a rail tong. This hook is used to fasten to the piece of rail being raised into the car. On the other end is a clutch, also made from a rail tong, by bending the handles at about a 45 deg. angle. This clutch is arranged to anchor to the rail in track behind the car being loaded. The cable operates through a 6-inch sheave wheel, which is attached to a post fastened to the side of the car. This post can be made from a piece of short mill rail.

The operation of this device is very easy and simple. It is necessary to have the rail marked to show the exact center before the grab hook is applied. The clutch which is fastened to the track behind the car is operated by one man, who holds it solid and tight while the car is moved ahead far enough to raise the piece of rail above the side, then two men can turn the rail around to allow it to drop into the car when the man operating the clutch releases it. Then the clutch is moved ahead and anchored to the track again, as the car is moved to the next piece of rail to be picked up. Rail along the tracks can be loaded in this manner about as fast as it could be handled with a derrick car, and few if any more men are required to do the work.

35. Portable Power Track Drill.

The portable power track drill is one of the coming labor-saving devices. There is now such a machine on the market, consisting of a small gasoline engine, belt connected to a drill designed to be clamped to the rail. The engine and drill weigh 300 pounds. Such a drill has a capacity of 240 holes per day, including necessary moves from rail to rail.

Improvements along the lines of conservation of weight, increase in portability and decrease in number of parts will undoubtedly develop a machine of decided value to the track maintainer. There seems no reason why the same machine cannot be fitted with a device to tighten the nuts on track bolts inserted in the newly drilled holes.

Appendix E

THE NEW ECONOMY

A MONOGRAPH

BY E. R. LEWIS.

The souls of men stirred to their depths by the spirit of that vast discontent of which the World War was a result, are by no means free of the aftermath of unrest which precedes the dawn of a new era of peace; the great reward for which America took up arms to defeat that enemy whose materialistic ideals threatened the life of Democracy.

The Nation, shaken by this vast upheaval, has not yet become adjusted to those new conditions which must govern the subsidence to the new level of the affairs of men engaging again in the pursuit of peace and happiness.

There is grave cause for consideration of our future attitude toward the business of the future.

Among matters of most import to the American people is the future of its lines of communication, its great arteries of commerce, its chief lines of rapid transit, the steam railroads. These highways must be maintained in serviceable condition, for on their efficiency depends all other industry, the very maintenance of life itself.

The growth of the Nation, made possible by the building of the railroads, is stunted the moment the wheels cease turning. Continuous service demands continuous maintenance. Efficient service demands efficient maintenance. Efficient maintenance demands efficient labor. Labor conditions are changing with the times, changing daily. Do those who must formulate the railroad policies of the future realize and recognize these changing conditions? Are they so closely in touch with the man behind the pick that his viewpoint is unmistakably clear to them? It is safe to say that they do and that they are. And therein lies the belief that this dawn of reconstruction will gradually brighten into the full glare of a new era of railroad maintenance so vitally necessary to the corresponding excellence of operation demanded from all sides.

When it becomes necessary for the price of labor to be reduced in ratio with the prices of all foodstuffs and other necessities, the costs of which are now at war time level, it is certain that maintenance of way employees will not suffer from reduction of wages "below the market."

Experience, best of teachers, has taught the unwisdom of such a course so thoroughly that railroad men cannot forget.

The comparative ultimate economy of the permanent employment of trackmen as against the hiring and firing, from season to season, has been made so plain in practice that most railroads now allow much work to be done in winter months that was formerly done in summer. The slack season is thus fast disappearing, while the work is better performed by a moderate permanent force of skilled men, which has replaced the hordes of temporary workers who once were hurried through the work in half the time to the detriment to all and everything concerned.

The new way is the economical way. The retention all the year round of a force of maintenance of way workers assures efficiency in in itself. Like other large employers of labor, the railroads have had a deal of raw material in the past. Out of the changes wrought in the last two years comes the call for a judicious seasoning of quantity with quality. May the call be heard, and may it be answered with steady application of the remedies which are being so promptly applied by the industries with which the carriers must compete as employers of labor.

Permanent employees are best retained in reasonably good permanent quarters. Working conditions should be commensurate with the quality of the labor employed. The grading of the service gives the laborer something to work for, creating the ambition that the old dead level wage discouraged. Flexibility in the rate of wages is dangerous unless handled by some one at the head of the organization who has vital interest in finance and in the results to be obtained from labor. But flexibility there must be to get most economical results.

The efficiency of labor is said, with reason and truth, to have decreased greatly in the near past. Prominent among reasons for this receding efficiency of labor is a corresponding and really alarming decrease in efficiency of supervision. Those who claim that the railroads, and especially the maintenance of way departments, are under-officered have seemingly incontrovertible evidence at command. But this is not the whole story or indeed the great part of it. One great weakness in the labor situation is slackening supervision. The slackening of the supervising of those supervisors now employed is a condition to be faced and fought. It is a condition of mind born of the times we live in. It can be overcome by right living, by right thinking, by earnest hard work.

There is a why to every carelessness, to every oversight, to every extravagance. What are needed on railroads are men who think for themselves—men who remedy evils because they know their causes. In no other way can we get rid of waste. In no other way can we get the best service out of the facilities we have.

Now is the time, at the dawn of this new era, to plan practicable economies: Wages a shade higher than the market; working conditions a bit better than the average; working methods that will save materials; programs of work that will divide properly the time spent on various items; supervision that is intelligent, not ordinary and dull, but bright and always alert to discover advantage. There is no gainsaying the statement that with less money and better application of gray matter we should obtain better results. Coöperation and correlation of officers, frequent meetings and well-laid plans may prove to be the best first steps toward the new economy.

The full advantage will readily develop as the plans are made item by item. The time is now. The place is here. The brain and the brawn are at hand. Is the thinker doing his part? Autumn will tell the tale.

DISCUSSIONS

DISCUSSION ON SIGNALS AND INTERLOCKING

(For Report, see pp. 327-272.)

Mr. J. A. Peabody (Chicago & Northwestern) :—In the text there are two slight errors. The plates on pages 351 and 352 are reversed in position, but reversing the headings will take care of the trouble. In other words, the one on page 351 should read "westward—C to A," and the plate heading on 352 should be "eastward—A to C."

It is recommended that this matter be accepted as information, and I so move.

(Motion seconded and carried.)

Mr. Peabody:—Your Committee recommends that the list of Railway Signal Association specifications and standards submitted as Appendix B by your Committee in its report in 1918 be published in the Manual as supplementary to the list heretofore inserted for the information of the members. I would so move.

Mr. H. R. Safford (U. S. R. A.) :—Since this report was made, there has been a meeting of the Railway Signal Association?

Mr. Peabody:—You understand that this matter which we are reporting now was submitted to this Association a year ago and turned back for further consideration on the part of this Association.

Mr. C. E. Lindsay (U. S. R. A.) :—In the interest of the Committee on Outline of Work, have any conclusions been reached by the Signal Division which would modify the work for next year?

Mr. Peabody:—All we submit here has been passed on and approved by letter-ballot by the Railway Signal Association.

I move that the first half of the matter shown on page 355 be approved.)

(Motion seconded and carried.)

Mr. Peabody:—Your Committee recommends that the submitted list of Railway Signal Association specifications and standards submitted with this report as Appendix B and shown on page 355, be published in the Manual as supplementary to the list heretofore submitted or inserted for the information of the members, and I would so move, Mr. President.

Mr. Lindsay:—Many of the members have not had an opportunity to look over these proposals, which are to be inserted in the Manual, and for the sake of the Manual we ought to follow the practice established last year and that is, to have it go over until the following convention, so that the members would have an opportunity of going over the matter, and if they have any objections, be prepared to present them to the next convention. We discussed that feature last year. To safeguard the Manual, I believe it is necessary.

Mr. Peabody:—The list is given only as information for the members of this Association, so that they will know where to look for such material when they have use for it.

Mr. Lindsay:—I question whether the amendment would fully cover

the situation unless the membership had an opportunity to see the Signal Committee plans; but if they are interested in the subject by title, they would have the opportunity of seeing the Signal Committee plans. I have in mind particularly the subject of ladders. I recall a case where a standard ladder designed by a Signal Engineer was to be applied to a tower, and the manner in which that standard ladder was applied was perfectly absurd, if not dangerous, so that it seems to me that is a question that might be interesting to some of our members, before the plans are approved, by their insertion in the Manual. Therefore, I move that this subject lay on the table until next year.

Mr. L. S. Rose (Cleveland, Cincinnati, Chicago & St. Louis):—I think we are making a mistake to put that motion over. If these drawings are shown in the Manual with a reference to where these plans can be seen it will assist the members of this Association who have the Manual, otherwise they don't know anything about it. The members of the Signal Division have this, and if we were to have printed in the Manual a list of the numbers of the drawings with their names, and where these things can be seen, it would be very valuable—it will be very helpful to the members.

The President:—Isn't anything in a Bulletin just as accessible as it would be in the Manual during the next year—to see these drawings and what the numbers refer to?

Mr. Rose:—I have a lot of Manuals around, a lot of Bulletins around, and it is hard to find those things. If you are in a hurry and want to find them, it is very difficult.

The President:—It is your idea that we made a mistake last year when we referred it back for a year?

Mr. Rose:—Yes.

Mr. J. L. Campbell (El Paso & Southwestern):—If this matter is included in the Manual, it becomes the recommended practice of this Association. I believe the conclusion of the convention last year was right and that matter of this kind should go over one year.

Mr. H. A. Lloyd (Erie):—It is my opinion that if we took those plans and made maps of them and distributed them in the form of a Bulletin, then every member of the Association would be able to peruse them at his own leisure.

Mr. W. A. Christian (Interstate Commerce Commission):—I would like to ask Mr. Peabody if the drawings of the Signal Division are too large to be incorporated in the A. R. E. A. Manual? Many of our members do not have access to the Signal Division Manual or Proceedings, there are many men in this Association who do not see them, and if they are not too large, I think they should be incorporated in our own Manual, so that the members would have a copy.

Mr. Peabody:—The Manual of the Signal Association now consists of something over a thousand pages. We are only referring to this Association such material as has been actually adopted by the Railway Signal

Association. As to size, I am rather of the opinion that it is somewhat larger than the Manual of this Association, although I could not say offhand.

Mr. Christian:—There are twelve drawings, if I understand this report correctly. I do not ask to have all of the Signal Division's Manual printed with our Manual, but only these twelve drawings to which you refer.

Mr. Peabody:—You understand that this is only adding to a long list which we have submitted from year to year heretofore, and to do what you request would mean that we would have to, I suppose, issue all of those that have heretofore been listed.

Mr. Christian:—What I have in mind is that all members do not have copies of the Signal Division Manual; they do not know where the drawings can be found, or have access to them, if they did know.

Mr. Peabody:—I suggest the best way to do would be for members to become identified with the Signal Division, if they are interested enough.

Mr. W. C. Cushing (Pennsylvannia Lines):—We have this same kind of a discussion year by year, and we do not seem to have settled in our own minds the relation between the Signal Division and the Association. My recollection of our last action in regard to this is that this which is now requested to be placed in the Manual is in the nature of a bibliography, and there is no reason why we should not accept it as such. It is a catalogue, an information index. It is the work of the Signal Division and not of this Association, and is simply put in our Manual for ready reference. There seems to be no reason why this should be held over a year for that purpose, because we are quite well aware from the action in past years that no one has ever checked up the last list which has been published, and it would not do any good if it was, because it would be simply a criticism of the work of the Signal Division. When this Committee publishes a report on a subject in which our Board of Direction has directed it to work, it is published in our book, but the work of the Signal Division is its own work originating in its own body, and they are offering it to us for information, and it seems to me entirely right that the action as recommended by this Committee should be carried out, as it is a good thing for us to know where to find this information.

Mr. John G. Sullivan (Canadian Pacific):—I want to second what Mr. Cushing said. The expert is a man with sufficient knowledge to study a question put up to him, and if I had to study a question of signaling, I would probably go to the Manual and I would like to get as much information from that Manual as I could, and if I was interested in the subject I would buy the books that Manual refers to. I second Mr. Cushing's idea.

(Motion to include information in Appendix B carried.)

Mr. Peabody:—Your Committee submits on page 329 a report on Subject 4 and recommends its approval and publication in the Manual.

Mr. Safford:—Would it not be better if the second clause of that recommendation could be expanded to contain a little more to indicate the character and conditions under which other types of advance information can be substituted for this condition? It says: "Overlaps are necessary for opposing movements, where adequate advance information cannot otherwise be provided." Is that capable of being a little more definitely specified?

Mr. J. C. Mock (Michigan Central):—The conclusion was reached after the Committee agreed it was best to provide trains with proper advance information. The use of a second distant signal for some special cases for double track operation was preferred to the use of an overlap.

For single track true approach indications to home signals are not provided, because generally the conditions will not permit. Therefore, the overlap is quite necessary, but only on single track is it justified as against approach indications.

Mr. Cushing:—I would like to have a little explanation of just what the meaning of this overlap is as used in this connection on single track roads; how long it is, and so forth.

Mr. Mock:—The Committee does not advocate the overlap, as you will note in our conclusion.

The overlap is the *extra* distance between home signals, that is, the allowance beyond the home signal for stopping of a train where the engineman cannot see the stop signal indication far enough ahead of him to stop at the signal.

In single track it happens the overlap is often the distance between two opposing home signals. In general, it is an overrun protection beyond a home signal.

Mr. Cushing:—Is not the distant signal indication or advance signal indication sufficient for that purpose?

Mr. Mock:—We think so. The overlap is now used on single track. It was used extensively on double track because it was economical, but it is now regarded poor practice to use only home signals, as many home signal locations are such that without approach information it is physically impossible to stop trains at them. An overrun section or overlap was provided to afford protection from the rear, that is, an extension of control greater than the distance between two home signals. This enables a train to hold the second home signal for the overlap distance. Good signal practice now gives the engineer information before he gets to the home signal.

Mr. Cushing:—I believe a stop signal, for the proper enforcing of discipline, should be used as such. A clause like this should not be put into our Manual without very careful consideration. Mr. Mock himself says he does not believe in it, and yet it is recommended to go into the Manual, and I am opposed to that motion.

Mr. L. S. Rose (Cleveland, Cincinnati, Chicago & St. Louis) :—I think we had better get a picture of what we are talking about and then we will understand it. It is a pretty technical subject, and I believe there are many here who do not comprehend it.

Mr. Mock:—Given a single track railroad having distant indications for both directions and two trains approaching in opposite directions receiving clear distant indications at the same moment (which means that the home signals are clear) and each having set the distant signals at the same moment. They are not properly protected. A preliminary control in one direction to prevent the above condition would mean the spacing of trains so great that they could not be got over the road or into the sidetracks and meeting points. So in single track operation it is not practicable to give true distant indications under all circumstances, and therefore overlaps are provided, overlap being the protection the engineman has if he should overrun his home signal.

Mr. Sullivan:—The last remark of Mr. Mock makes me more confused about this thing than I was before. As I understand this matter of overlap, a train going in one direction would have a certain overlap—we would say that the train going east would set the signal against the westbound train before it reached the signal. The Chairman in his last remark said it was a space in which you were permitted to run beyond the home signal.

Mr. A. G. Shaver (Consulting Engineer) :—If this question is dark in the minds of some members, we will try to give an illustration. There are two conditions which should be kept in mind where the overlap is used. Let us first consider a double track where we have following movements only. Some railroads have found it necessary in the past to use overlaps where three position signaling is in use. Assume that glass (pointing to drinking glass at one end of table) is one signal, that pitcher another signal, and this pitcher another signal. An overlap for that first signal down there might be this one block (indicating space on table between second and third signals). We are going this way; that is an overlap on double track.

Now, we have another condition, an overlap on single track. This is a single track (indicating space), and the trains are running both ways. We still have the glass down there, the pitcher there and the pitcher there. The train passes that signal up there, and we will assume that the first signal it gets is clear, but goes to stop behind the train, and the train proceeds and passes this pitcher. This is the second signal (indicating pitcher) and this is set at stop as the train passes. They get in this locality, part of the overlap, and both the signals are at stop, and we will assume the overlap passes down to this platter. As soon as they pass, that signal will clear from stop and there is only one signal behind them, and that is here (indicating), and they will proceed, and have the same process of signaling in sequence.

Mr. Rose:—What you say, in substance, is that part of the time the

train is protected by two home signals standing at stop, and part of the time the train is protected by only one of these signals.

Mr. Shaver:—Yes, if you have only a partial block overlap. I refer to a part block overlap. If there is a full block overlap, they are protected by two signals.

Mr. Rose:—You have two red signals behind the train if you have a full block overlap?

Mr. Shaver:—Yes.

Mr. Rose:—The engineer has nothing to say about it. If he gets a home signal, he stops. Without overlap he has one red signal behind him all the time. Is that right?

Mr. Shaver:—That is right. Here is the overlapping for a single track. Assume these are two signals, with the entrance signal going west, and this is the entrance signal going east. They are opposing signals. If we had no overlap at all, two trains approaching toward each other, coming to these signals at the same instant, would get an indication of clear and each get into the block under a clear signal. We have got to have an overlap to protect against that. That glass up there and this glass here govern that way (indicating) and the pitcher there and that pitcher there govern that way (indicating). We have a train here, and this train gets a clear signal, and when this train is approaching this signal, that signal is set to stop up there; the other train approaches to this pitcher, and gets the stop signal, and this space here is the overlap.

Mr. Rose:—I think he has a preliminary section and sets one signal before he gets to it. It is not an overlap, but a preliminary.

Mr. Shaver:—An overlap in one direction and a preliminary in the other, if you wish to put it that way.

Mr. Safford:—What bothers me about this rule is the positive statement that "overlaps are necessary." That is the opening part of the rule, and I am not entirely clear in my own mind as to the following part of the rule. I want to get clear in my mind what is the condition that permits that rule to be set aside and rendered inapplicable. It says that overlaps are necessary except where other methods of advance information can be used. What is the condition that would make the overlap undesirable in single track operation?

Mr. W. M. Camp (Railway Review):—There seems to be an idea with many of the speakers that an overlap, of which some of the gentlemen have spoken, will permit rather loose running on the part of the engineman; for instance, because he is permitted to pass a home signal. Mr. Rose has been asking questions to draw out information. Will he or some other Signal Engineer present make it clear as to whether or not an engineman, running on a track which is provided with overlaps, is allowed "permissive" running? or why, if he should pass a home signal in the stop position, he does not, by that act, necessarily disregard the signal?

Mr. Mock:—Mr. Camp has made one point against the overlap. The

engineman realizing he is in overlap territory where he has protection, even though he should overrun a home signal, is more likely to overrun.

The other objection is that it does reduce the capacity of the line because if you allow a train to stand anywhere on the overlap it is holding at stop two signals in the rear.

Mr. Rose:—This so-called overlap is substantially a preliminary section of the track which will set the opposite home signal on the single track will not reduce the capacity of the line. On the double track that scheme, as illustrated here, will, I think, do it, but on single track I do not see how it will.

Mr. F. L. Dodgson (General Railway Signal Company):—Perhaps I can clear this situation a little. We speak about overlap on a double track, and the Committee says that an overlap for the purpose for which it is used on a double track is not necessary. On a single track it is necessary to have control of one home signal, extend beyond the next home signal for the purpose of providing a preliminary section, and preventing head-on collisions, or, in other words, to give protection for opposing movements. Unfortunately, that same preliminary section when trains are running in the same direction becomes an overlap. It was put there, not for overlap purposes for following trains, but for protection of opposing trains. Unfortunately, the Committee has called it "overlap" in single track. It ought not to be called overlap in single track, but "preliminary section."

In answer to Mr. Rose's question, an overlap on a single track will not reduce the capacity of the line to the same extent as it would on a double track, but at the same time it does reduce the capacity to some extent, because trains cannot be made to follow each other as closely over the line; so there has been devised in later years a system of single track signaling in which this preliminary section fulfills its function as far as opposing trains are concerned, but does not act for following trains. That system is pretty general at the present time.

The President:—There seems to be two lines of thought here. One man down on his road talks about preliminary sections, and another man talks about overlap. The man who uses preliminary sections wants them called preliminary sections, and the man that calls them overlaps wants them called overlaps. As there is that variation and some chance for a misunderstanding under this practice, perhaps it would be well to refer it back to the Committee and let them bring it in next year, with a little more full explanation than this of a preliminary section. Some of us would not know a preliminary section if we met it; they should explain it so that we would know that when one man talks about an overlap he means what the other fellow calls a preliminary section. Anyone who thinks that way might make a motion to that effect.

Mr. Safford:—I so move.

The President:—The Committee withdraws that, and we go back to original motion. It is moved and seconded that Section 4 be taken as a

progress report and referred back to the Committee with instructions to go into the description of the difference, if any, between overlaps and preliminary sections.

(Motion carried.)

Mr. Peabody:—Section 5, "Report on the various types of light signals for day and night indications."

On page 364 there is an illustration of the position of light signals. Unfortunately, there is a slight error in "stop and proceed" (Rule 504) indication. A light should be shown vertically below the second light from the left in the upper indication. That would be directly opposite the center light of indication No. 3. If you make that slight correction that will take care of it.

The report on this subject is submitted in Appendix C, and we move that this be accepted as information.

Mr. Lindsay:—The Committee on page 356 have given some definitions. Are they prepared to submit those for insertion in the Manual?

Mr. Peabody:—It is for this report only; in other words, these definitions are used in this report.

(Motion carried.)

Mr. Peabody:—"Report on automatc train control." Before presenting this, I will ask Mr. Eck to make a statement.

Mr. W. J. Eck (Southern Railroad):—On page 370, near the bottom in the description of the "American Train Control System" on the Chesapeake & Ohio Railroad, the Committee has inadvertently done the Chesapeake & Ohio Railroad an injustice, in that we say: "No especially novel points of construction are indicated." That has come about from this reason: The report was prepared several months ago, transmitted to the Secretary for printing in a Bulletin, and naturally does not contain the developments of the last two or three months. This system has been developed on the Chesapeake & Ohio largely through the efforts of the Signal Engineer of the Chesapeake & Ohio, and it does have points which are different from other installations which have been made recently. The Committee expects to present at the proper time a full and complete description of the system, which is not available at the present time; in fact, the installation is now being made, and is just about ready for service.

Mr. Peabody:—Your Committee has made its report in Appendix D, and I would move that this be accepted as information.

(Motion carried.)

Mr. Lindsay:—I think it would be in order for the Chairman of the Automatic Train Control Committee to make a statement as to the organization of that Committee which has occurred since our last convention. The last Train Control Board was in existence several years ago, and has been revived by the action of the United States Railroad Administration. That fact is not recorded in our Proceedings.

The President:—It seems to me that it is up to the Committee to find

out and report the fact that there is one in existence. It has just started to do some work, and that is all that could be said of it. It has simply been appointed and organized, and is starting in to work along the line of proving, if possible, the practicability of automatic train control. Probably the Signal Committee will be very busy on this subject by another year.

Mr. Peabody:—On the other subjects, the Committee reports progress.

The President:—If there is no further discussion, the Committee will be excused, with the thanks of the Association.

DISCUSSION ON CONSERVATION OF NATURAL RESOURCES

(For Report, see pp. 101-117.)

Mr. R. C. Young (Lake Superior & Ishpeming):—This Committee this year were obliged to change their report several times before they were ready to submit it, because of the changes in existing conditions due to the war, the signing of the armistice, etc., but we have prepared a short report on conservation of fuel, thinking that was one of the most important things before us at this time. Prof. King is largely responsible for this report, and I will ask him to say a few words to the convention about it.

Prof. E. E. King (University of Illinois):—A large portion of the report this Committee presents is based upon and taken from the recommendations of practice of the Fuel Conservation Section of the Division of Operation of the United States Railroad Administration. The Fuel Section spent a great deal of time and spared no pains in preparing such bulletins as would lead to the conservation of coal in railroad work. The Committee felt that it could do no better than to incorporate in its report many of the recommendations of the Railroad Administration.

Mr. William McNab (Grand Trunk):—I trust that the convention will understand that this report of the Committee on Conservation of Natural Resources is merely one prepared and furnished to the convention as information. As Prof. King has just said, the information was obtained from those who are specially engaged in the work from one end of the year to the other. Any data that is in it has been obtained from official sources, and it is merely presented as information.

The President:—You have heard the explanation in regard to this report.

Mr. Young:—I move that the report be accepted, as a report of progress.

(Motion carried.)

Prof. S. N. Williams (Cornell College):—Mr. Chairman, I rise to a question of privilege. As has been stated, the report of the Committee on Conservation of Natural Resources was limited to the consideration of the subject of coal. One of the points which was assigned to the Committee for its consideration by the Board of Direction was measures for conservation of human life and energy. The situation in this country at the present time is such that I deem it necessary to call your attention to the urgent necessity for our consideration of the conservation of life, health and energy, so I trust you will pardon me for making two or three statements bearing on that for your consideration during the year.

Mr. Lloyd George has said, "The health of the people must be the special concern of the State.". A report from London says that "for the first time since the establishment of a system of registration, the deaths exceeded the births in England and Wales in the last quarter of 1918." A

statement also made by the former Ambassador to Turkey predicts an early labor shortage in this country of five million men.

I want to call attention also to the fact that the casualties in American coal mines in 1918, as reported to Secretary Lane by the Bureau of Mines, "include 2,575 men, in one peaceful industry during this war," says the Secretary. The beloved Wellington, in the introduction to his book on the economical theory of the location of railways, characterizes "the avoidance of waste" as one of the first essentials to successful financial construction and operation of railways.

Now, it seems to me that while we have been unable to present a report for your consideration, yet it is a subject which is well worthy of the attention not only of every member of this organization, but also of every citizen in our Nation. I am appalled when I see from day to day in the newspapers reports of accidents causing the deaths of women and children, which were caused in most instances by gross carelessness, and I would characterize that as "the slaughter of the innocents," so far as women and children are concerned.

I submit, gentleman, that one of the most important subjects for every one of us to consider at the present time is the prevention of this loss of human life, which is caused by carelessness.

We have some of the most difficult problems of all time and the solution is constantly causing alarm and concern to those who have our best interests at heart, so I trust, gentlemen, that you will be considering this item of our report which will be taken up again, and we shall probably report on measures for the conservation of human life and human energy.

When I look at you, gentlemen, and think of the value of your lives, your energy and powers of body and mind, I think also of the possibilities of those children who are carried over to the other world, through no fault of theirs, and are pitifully deprived of the magnificent opportunity of human existence, so I beg you gentlemen to consider this question and keep your eyes upon it, as being one of the most important questions which face our country at the present time. I know that each one of you, whether in the matter of your own children or your own relatives, have sufficient consideration for the good of the Nation and the development and progress of this Nation in the near future to do all in your power to bring about a change in this system of waste caused by the carelessness of some person or persons who are positively reckless and should be punished for it.

I submit to your intelligence, gentlemen, whether that is one of the questions we should all face most seriously and I invite your most earnest consideration of the subject. (Applause.)

The President:—If there is no further discussion, the Committee is relieved, with the thanks of the Association.

DISCUSSION ON TRACK

(For Report, see pp. 65-84.)

Mr. W. P. Wiltsee (Norfolk & Western):—The Committee has reported progress on a number of subjects, and the principal one they are making a report on is Subject No. 2, "Report on Typical Plan of Turnouts, Crossovers," etc.

(Mr. Wiltsee then read the matter under subjects 1 and 2 from the report, as found in Appendices A and B, and said:)

Since this report was prepared, the Committee has continued its work, and has prepared tentative plans for 22 and 30-ft. switches, 11 and 16 rigid frogs, 8 and 11 spring frogs; 8 ft. 3 in., 11 ft., and 16-ft. 6-in. guard rails, and also have considered plans for a No. 20 manganese frog. They are not, however, in shape to present at this meeting. It has been necessary to make plans that could be used under all traffic conditions, and we have endeavored to do this and make a sufficient number of plans so that they could be used under any conditions in this country, at the same time not getting too many, so that we would have too many standards. We have endeavored to keep them down to a minimum.

This report is the report of practically the entire Track Committee—not of a few members—but practically all the Committee.

Mr. President, I move, on behalf of the Committee, the adoption of these plans by the convention.

Mr. A. Montzheimer (Elgin, Joliet & Eastern):—I notice this report does not show the clamped frog. We have been using the clamped frog for over twelve years, and it has been a very satisfactory frog. It represents an improvement in many ways over the old bolt frog. We have gotten away entirely from the loose bolts and troubles that go with it, and I think it would be a good thing if this report was so made that we would be given the privilege of using the clamped frog and still be in line with this practice.

Mr. C. W. F. Felt (Santa Fe):—I second that suggestion, and it occurred to me that a good way to cover that would be to prepare an alternate plan. The Santa Fe has used the clamped frogs for a good many years, and thus far, at least, they have proven very satisfactory, and my information is that that is true of the practice on other roads in the Southwest. I cannot say as to the practice in the East, but I would suggest that unless the Committee already has that in mind, that they be so instructed.

Mr. Wiltsee:—The Committee had tentative plans drawn up on the clamp frog. They took this matter up with two or three members of the Committee, members on Western railroads, and from their experience—their recommendation, rather—we did not include clamped frogs.

Mr. A. H. Mulliken (Pettibone, Mulliken Company):—Mr. President and Gentlemen: Standard plans have been prepared for clamped frogs, and I think the suggestions that have been made here are all right. We

have alternates on switches, we have alternates on spring rail frogs, and it would seem fair to 60,000 miles of road that are using this clamped frog that there should be this alternate, and with your permission I will leave with the Secretary standard plans that have been prepared and that are uniform with those in the Bulletin.

Mr. J. L. Campbell (El Paso & Southwestern):—The El Paso & Southwestern has been using clamped frogs for a good many years. I believe that these plans providing recommended standards ought to include the clamped frog. I have no objection to the bolted frog, but the clamped frog ought not to be excluded from the recommended practice of this Association.

Mr. L. Yager (Northern Pacific):—I would like to confirm what has already been said on this subject by the previous speakers, and add that the experience of the Northern Pacific, with reference to the use of the clamp frog, is the same as that just outlined. We are using it as a standard on secondary track and would like to see that practice embodied as an alternate proposition in the report of this Committee.

Mr. A. W. Newton (Chicago, Burlington & Quincy):—We have never used the clamped frog on our system at all. We have had no experience on which to base any decision.

Mr. R. S. Parsons (Erie):—I do not think the question before this meeting at the present time is whether a clamped frog is a good frog or not. If I understand correctly, the question now before us is whether we shall adopt the report of this Committee, and embody its essentials in these standard plans. I have in my office a shelf full of reports of Proceedings of these conventions. The shelf is now about six feet long. It is full of Proceedings from Vol. 1 to Vol. 20 something, and the Manual of Recommended Practice is about one-half inch thick. If I want to know anything, I go to my Manual first, and if I do not find it there, and I rarely do, I then go through the other 5 ft. 11½ in. of my shelf to find the information. Consequently, I think it is essential that this organization which has a life now of some twenty years begins to get more matter into its Manual, matter to which we can refer. I do not understand that the life of any Committee terminates with the personnel of that Committee, or with any report that the Committee may make. A Committee can make a report, and it may get its findings in the Manual. But the Manual may be modified later. To my mind it is essential that we get more matter in the Manual.

The Track Committee has spent a good deal of time on these plans, and they have prepared a most excellent set of standards.

This is a peculiarly excellent time to have standards adopted. The tendency of the Railroad Administration has been to adopt standards, and it is an excellent time to have standards adopted. These plans have been carefully gone over and embody the ideas, of not only the railroad operating and maintenance of way men, but also of the manufacturers, and consequently if we had these plans adopted and included in our Manual, the

trackman would find something tangible on this particular question, which is sometimes so troublesome.

I do not suppose that any other question on a railroad has received any more attention, and I doubt whether any other problem has had more plans drawn to cover it, than this question. I have been interested in frogs and switches for a good many years, and my experience has been that the points of difference are non-essentials.

If this Committee has provided for the essentials, it seems to me that we should adopt them and try to get a standard line of frogs and switches, so that every new maintenance of way man or Engineer will not begin to introduce his own ideas in this fundamental question, and I most earnestly recommend the adoption of this report and particularly the placing of these standard plans, so far as they are compiled, in the Manual. That does not mean that they are complete. The clamped frog can be developed and introduced at the next meeting, if that is considered desirable, and if any features develop in these plans that are not desirable they can be modified, but the best way to have them modified is certainly to get them in the Manual.

Mr. J. L. Pickles (Duluth, Winnipeg & Pacific) :—I want to endorse what the last speaker has said, and to that end I would like to see the Committee adopt either the details of 1000 or 2000 as shown on the plan 101. There seems to be very little difference in the shape of the points, and personally I prefer the detail of 2000. I see no good reason for having so many details and standards. If we are going to get up standards, let's have them. If we are going to have standards designed to everybody's notion, we will have no standards at all, and we will be in the same position as we now are.

Mr. H. R. Safford (U. S. R. A.) :—There appears to be detailed two different types of adjustment. My recollection is that there are several types in use, and if the effect of this report is to limit the adjustment to the two types shown, there might be a question involved as to whether some restriction is not being made, and whether other types ought not to be portrayed, particularly the third type to which I have reference, unless they have been found to be faulty.

Mr. Wiltsee :—Plan 202 shows a number of special features. We have allowed two types of adjustments, and in the opinion of the Committee that was sufficient. Those to which we give preference are shown in Plan 201.

Mr. Safford :—Plan 202 is merely submitted as information?

Mr. Wiltsee :—As an alternate plan.

Mr. C. W. Baldridge (Santa Fe) :—In the matter of adopting the bolted frog as recommended practice, and not showing any alternate plan, or a permissible plan of the clamped frog, I remember a year or two ago there was some criticism, in the convention of this Association, of various railways for not conforming to the recommended practice which is published in the Manual. It has already been shown in the dis-

cussion here that a large mileage of the railways are using successfully and satisfactorily a clamped frog, and so that these roads may not be subject to the criticism of not conforming to the recommended practice, unless there is some real good reason for recommending against the frog, it would appear to me to be proper to instruct this Committee to select an alternate plan permitting the use of the clamped frog. I do not believe there is any argument which justifies a ruling against the clamped frog, and I feel for that reason we should support the suggestion, asking the Committee to present plans for that type of frog in next year's report.

Mr. J. E. Willoughby (Atlantic Coast Line):—I ask the Committee what governed them in determining the length recommended for the frog and the switch point?

Mr. Wiltsee:—The length of the frog is partially governed by the cutting of the rail. As I read this report, the different length of frogs work out for a 33-ft. rail better, and there is no waste in material. The length of switch points was adopted by the Association a number of years ago.

Mr. Willoughby:—Is it the idea of the Committee that the cutting of the rail is more important than any other feature of the design?

Mr. Wiltsee:—No, sir. We met all other features of the design, such as length, spread at heel, and every other point we could think of, and still saved in cutting the rail.

Mr. John V. Hanna (Kansas City Terminal):—I was looking into this question a few years ago in connection with the supplying of switch material for a terminal, and I asked the manufacturer what was the advantage to the company in using 16.5 ft. points instead of 15, and he said there was none. We paid for the material we actually received, and there was no economy for them in cutting the 33-ft. rail in two.

If the Committee can get it, I would like to have a little more information along the line of just how the purchaser gets the benefit of that economy in cutting up the rail. I understood at that time—it may be different now—that the manufacturer could make some use of the pieces cut; it may be that they only got scrap value for them, but I know at that time they did not offer any concession in the way of price that to my mind made it worth while to take an extra length.

Mr. Mulliken:—I will reply to Mr. Hanna. In cutting rails and making frogs and switches the material is handled more rapidly than you gentlemen have any idea of. It is nearly all handled by machinery now, and it is a great economy and convenience in cutting a 33-ft. rail to cut it right through the center. I do not think it is fair, in making 15-ft. switches, to charge the roads for 16.5 ft. of rail, because if it is necessary to make a 15-ft. switch, we could get 30-ft. rails from the mills.

Mr. Wiltsee:—The Association adopted 11 ft. switch and a 16 ft. 6 in. switch a number of years ago. It seems to me the advantage is purely

with the railroad company. If you get a switch 16 ft. 6 in. long you have a better switch, with a better angle.

Mr. Hanna:—I will admit there is an advantage, but how much advantage is there in the angle? On this question of the waste it may be that the manufacturers now figure a little differently, but they told us then that we did not really make anything by taking the longer point.

The President:—Naturally the length of the frog or the guard rail or a switch point depends on the merchantable rail that it is made of. In the old days of the 30-ft. rail we used on the Santa Fe System a 7.5 guard rail. When we used a 33-ft. rail we divided the rail into four pieces, just the same. In our switches we used 10 and 15-ft. points when using 30-ft. rail, changing to 11 and 16½-ft. points when 33-ft. rail was adopted. My idea is that frogs, switches and guard rail should be so designed as to use up the standard length of rail, without waste in cutting.

The fact is, the amount of rail the switch and frog manufacturers require have to be allowed from the output of the mills for frogs, switches and guard rails. We have been for the past six months handling the rail proposition for the country and making up the rolling mill schedules, and the reports from the mills show that they roll from 350 to 750 tons a week for frog and switch manufacturers, therefore any waste that can be avoided, by economical design, means a good deal in rail saved.

Mr. Mulliken:—I would like to confirm what you have said, Mr. President, because I think as long as the manufacturers have been asked to participate in this meeting it is only fair that they should participate. There are twelve concerns making frogs and switches in the United States, concerns of some moment, and when they are running full time they will use over 400,000 tons of rail in twelve months for this purpose.

Mr. Campbell:—I have no objection to these plans for what they contain. My objection is on what they do not contain. Before the subject of frogs is finally disposed of I believe the plans should include a clamped frog and some additional adjustments of the connecting rod. If the Committee will consent to an addition to the motion directing it to recommend a plan for a clamped frog and make additional study of the connecting rod for next year's work, my objection to the matter as it now stands will be removed. I would like to see these plans adopted at this time with the understanding that the subject is not closed and that additional recommendations above indicated will be submitted by the Committee next year.

Mr. Wiltsee:—The subject is not closed by any means. It is only starting. If it is the desire of the convention that we include a clamped frog, the Committee is only too willing to do that.

The President:—I think Mr. Campbell and Mr. Parsons have ideas along the same line. We have a good start and there is no reason why anything cannot be developed, if it is found to be desirable, and I do

not think it is any reflection on anyone, if they do not happen to be using all of the frogs and switches that were turned out in this first get-together meeting. I am proud of this get-together proposition with the manufacturers and the Association.

I think there is a great big future for it. I do not want to see a thing come up here that we cannot get together on, and I think that we can get that matter up and settled probably by the next convention. I would suggest that Mr. Campbell make a motion as outlined in what he has just stated.

Mr. Campbell:—I move that the motion before the house be amended to include a direction to this Committee to bring to the next annual convention a recommended plan for a clamped frog and additional report on adjustments of the connecting rod.

Mr. Hanna:—Would this amendment prevent the Committee from going further into the question of the merits of the two types of frogs? and if they thought that the merit was decidedly in favor of either one or the other, recommending that one and not two? I speak of that, because I believe it is not a good idea to shut out consideration of the merits of the design. If two designs are of equal merit, the Committee can recommend two.

The President:—I do not think that we should start in with too much detail in regard to whether this, or that or the other is good. We are not closing the gate by adopting a standard. It has got to be reviewed from time to time, as our practice shows improvement over what we had before. A man that starts out to get a standard with the idea that he has closed the gate, and that he has to do nothing more on that standard for ten years, is about ten years behind the times. We have two of nearly everything else on this list. If we get this other on here it will be discussed back and forth. We can have that discussion and the Committee can discuss it, and get opinions as we have done on so many things, from various roads, and see how they are lined up.

Mr. Mulliken:—May I make a suggestion before the question is put? I judge from what I have heard here that there is not any question in regard to a certain number of railroads using this particular design of clamped frog. The only question is the one before the house, whether this should not be used as an alternate. You have two alternates on spring rail frogs. Why? To meet the practice east of Chicago and the practice west of Chicago. You have two plans of switch points. Design 1001 is used on every road west of Chicago, and 2000 is used on most of the Eastern lines. Why do you have two? To meet those conditions. You have got four alternates on switches. It seems to me that the question should be narrowed down simply to the question of alternates. It is not a question of quality, it is not a question of design. It is simply a question of accommodating the traffic in two districts of the country. Therefore it seems to me when these plans are prepared to conform to standard in shape, in size, and in design, the question

before the house is, why should not this be adopted as an alternative? In other words, why should roads aggregating 60,000 miles of track that are using those frogs be put on the plane of not conforming to the standard of your Association? It seems to me we do not have to refer that to a Committee, but that you are capable of deciding that here.

The President:—Our standards are young yet, you know. These things are all young. We are not getting out a finished product, and I do not like to see anything injected that looks as though we had finished the job.

Mr. Campbell:—My motion is merely an addition to the original motion. It does not affect the original motion as far as it goes, and if this amendment, if the motion as amended is adopted, it would merely carry with it instructions to this Committee to report to the convention next year a plan of a clamped frog, with additional study of adjustments of the connecting rod.

The President:—That is my understanding.

Mr. Geo. A. Mountain (Canadian Railway Commission):—It seems to me that Mr. Campbell's motion is to instruct the Committee. Now, this Committee in getting out these plans probably took into consideration all kinds of frogs. I quite agree with them. I would not use a clamped frog if it was given to me for a present; but it seems to me that that recommendation is not proper. It should be referred back to them to consider the question whether they would recommend it, and not instruct them. It seems to me if they are instructed, they have got to bring in a report on some kind of a clamped frog.

Mr. Wiltsee:—I will say that the Committee will be very glad to reconsider this matter of the clamped frog, and also further adjustments of the connecting rod, and if they decide that it is necessary and feel that it is advisable to present plans, they will be very glad to do it.

Mr. Campbell:—This motion, if adopted as amended, will also be an instruction to the Committee on Outline of Work. This Association cannot suffer any damage by having an opportunity to consider a recommended plan for a clamped frog.

(Mr. Campbell's motion carried.)

The President:—Now that did not carry with it the original motion.

Mr. Wiltsee:—I move that the convention adopt the plans for switch points, frogs and so forth, covered by Nos. 101-2-3 and 4, 201-2-3 and 10, 301-2-3-4 and 5, and 401.

(Motion carried.)

Mr. Wiltsee:—I move that Appendix C be received as information.

(Motion carried.)

Mr. Wiltsee:—I move that the subject matter under Appendix D be accepted as information and referred to the Master Car Builders' Association (now the Mechanical Section of the American Railroad Association).

Mr. C. E. Lindsay (U. S. R. A.):—I want to emphasize the fact that the weight on the wheel cuts a very great figure. A 1-in. flat spot on a locomotive or on a locomotive tender does more damage than we have any appreciation of, and I think that fact should be emphasized in presenting the subject to the Mechanical Section of the American Railway Association. Attention should be called to the fact so that they might differentiate, if they consider it necessary, in determining the limit of the flat spot under different loadings.

Mr. Wiltsee:—The Committee will add to the report to make it agree with the instructions of the Mechanical Section of the American Railroad Association on flat spots. They have made a report limiting the flat spot on freight car wheels to 1½ in. as instructed.

(Motion carried.)

The President:—That is all. We thank the Committee, and they are discharged.

DISCUSSION ON RECORDS AND ACCOUNTS

(For Report, see pp. 407-409.)

Mr. W. A. Christian (Interstate Commerce Commission):—Mr. President, I will not consume time in reading the work assigned to this Committee, because I desire only to submit this report as one of progress. Your Committee has been busily engaged on the subjects assigned to it, but the report presented does not show the amount of work it has performed. I move that this be accepted as a progress report.

The President:—Of course, this is something for the Board to put up to the Committee, but I think there is a lot of work that ought to be done by this Committee. I recognize that this Committee got out a lot of standard forms and thought their work was done, and they have been taking it easy for the last three or four years. I want to say that in the last three months I have found a big road of 10,000 miles that said they did not have a record of their ballast, rails or ties. They are not alone. They are rather alone among the big roads, but there are lots of roads in this country whose records are poor. We have been trying to get some information, and they throw up their hands, and say, "We cannot do it, we do not have any records of that kind," and I think that this Committee should look into the question of how we can get comparative expenses on the different roads. One road is calling for 550 or 750 ties per mile for 1919, another road calls for 250 to 350. There are any number of these things that I think this Committee should look up and study, so that we may get reports that are uniform and will give a comparison of similar work done by the different roads of the country so that we may know and study results obtained on different roads. Take the cost of maintenance per mile. There are some railroads, if they renew a 14-ft. pile bridge in kind, charge all but the ledger account to additions and betterments. There are other roads which, even in the case of a 1,000-ft. pile bridge, if no change is made in the type of the structure, charge it all to operation. We get these figures and compare them, and we say, "Here is a road being maintained for $1,300 per mile, while some other road is shown as costing $1,600 per mile, and we think this difference represents something, when owing to different accounting methods, the comparison is actually of no value. This Committee should recommend forms for getting information compiled in a uniform manner.

The motion is that the report of this Committee shall be received as a progress report.

Mr. J. L. Campbell (El Paso & Southwestern):—Before the motion is put, it is well to suggest that new questions have arisen in this matter of accounting by the relations now existing between the railways and the Government. The Government has agreed to return the railways to the owners in physical condition as good as when received. That involves the question of what had been done with the property during the test period and what is now being done with it during the period of control. It de-

velops that the relative conditions of the properties in the two periods cannot be very well measured in terms of dollars and cents because of the great changes in unit prices of labor and material.

This suggests that a better measure of comparative physical conditions is found in units of labor and units of material put into the properties during the two periods. It may be well for this Committee to consider some form of reporting units of labor and units of material.

Aside from the present situation units of labor and units of material going into the property will always be fundamental measures of the maintenance of the property. If such a record is comprehensively kept it will be a real addition to our accounting. Doubtless careful consideration is required to develop a form of recording such information, comprehensive and detailed, from which may readily be determined from month to month and year to year what is going into the property.

Mr. R. C. Sattley (Chicago, Rock Island & Pacific):—A number of railroads are endeavoring to be relieved of the requirement to furnish the Interstate Commerce Commission with copies of their profiles. Under Order No. 1 of the Commission, roads are required to furnish these profiles. In regard to records and accounts of betterments and additions, railroads ought to keep proper records, so that when information is desired as to costs it can be ascertained readily.

Mr. W. H. Courtenay (Louisville & Nashville):—As to keeping a record of ballast, I took occasion some twenty years ago to ascertain how much ballast there was on a line of railroad completed in 1868. The Louisville & Nashville had kept very good accounts that were instituted originally by the late Albert Fink, showing the quantities of materials used and the various expenditures. By merely ascertaining the amount of ballast purchased for this operating division, I ascertained it was sufficient to provide for 4-ft. depth of ballast under the ties for the whole length of the division. I had known that division since 1879, and to my certain knowledge there had never been at any time sufficient ballast put under the ties.

On one occasion we had great trouble with churning track—we have always had trouble with that—and to overcome it we ribbed the fills. One night, after we had made an excavation from the shoulder and down the slope, and timbered it, preparatory to filling the trench with rock, a farmer found the fill had given way, and flagged a train. When we examined it we found there was 10 ft. depth of practically clean ballast at that particular place.

We have made statements from year to year showing the amount of ballast on different divisions of the railroad. None of them are accurate. It is impossible to tell how much effective ballast is in place at any one time on railroads such as ours. We can tell how much we pay for each year, but how much effective ballast we now have cannot be told. Ballast is lost—it becomes dissipated—and to properly maintain a division it must have ballast every year, and every time the track is resurfaced a

certain amount of ballast is required. After it is placed in the track it is driven down. When the ballast is driven down into the roadbed, the effective ballast is only that which lies above the shoulders of the embankment.

We will probably be called upon to show how much ballast we have on each mile of road. I will defy anyone to do that on 5,000 miles of railroad with any success. Effective ballast will vary from 6 in. to 3 ft. in depth, particularly on new roads. If a heavy traffic is immediately thrown over a new line, it is necessary to use large quantities of ballast. If a new embankment is built, 40 ft. high, it is impracticable to provide for the settlement which may occur and maintain the rate of grade, and the sensible way to do is to build lines with very deep fills, subject to heavy traffic immediately upon completion to the established grades, and as they settle bring them up with ballast. It is not unusual for an embankment 50 ft. in depth, built according to modern methods, to settle four or five feet. Where there is four or five feet of ballast, and the Roadmaster afterwards builds up the shoulders, a place is provided for water to accumulate, the effect of which is to create slides.

It is impossible for railroads to give the complete details about ballast. It cannot be done.

I hope this matter of getting detail statistics, particularly with a view to determining whether the United States Railroad Administration maintains the track as well as the corporation did in the three test years ending June 30, 1917, can be reached in some practicable way. There can be a great deal said on that subject.

The President:—I have been through about the same thing. As you were telling about the 4-ft. ballast, I was wondering how many inches of leather we would have on our shoes if we added all that we had worn out in our lifetime. This ballast is worn out, and according to my notion, we have to decide on a certain depth of standard ballast—the Pennsylvania Lines have decided on 24 inches. This, you may say, is an arbitrary proposition, and no one has any right to do that, but there are many arbitrary things which are necessary, and if you are going to get comparisons you must have some arbitrary rules, instead of having 50 or 100 different standards of comparison.

I came in contact with an interesting case of ballast just after the Federal control. There was a road that had about six inches of ballast, in certain places, and the standard was 15. They wanted to put in five inches more. It had been customary to charge that to Additions and Betterments, but the Vice-President said, "No, that is put in there to take the place of five inches of ballast that is worn out," and that was true. That is the difference in practice; one road will replace ballast worn out and charge it to maintenance, another will put in ballast up to the standard depth and charge it to Additions and Betterments.

My thought is that you must get figures in some certain way in order to make comparisons.

In regard to Mr. Sattley's remarks about the profiles, I have received profiles for 230,000 miles of road, and I found it would take about 230,000 days to go over them and dig out the information.

Mr. W. M. Camp (Railway Review):—I think some interesting remarks on ballast have come out in connection with this report. We know that for a good many years past men have been figuring on the life of rail—what wear is allowable, what tonnage the rail will carry, and what is the life of the rail on curves, etc. Particularly since the valuation of railroads has been taken up, we have come to learn that there is such a thing as life of ballast. As ballast is renewed that which was formerly on the surface, or directly under the ties, becomes buried; and, as Mr. Courtenay says, when the ballast has settled down below the shoulders of the embankment, it then becomes roadbed.

One will find that there is no small loss of ballast from being blown off the track by the natural winds and by the currents of air set up by the motion of the trains. Then there is also the washing down of ballast by rains, especially where the shoulders are not well kept up. One may find a good deal of ballast down at the bottom of the slopes of the embankments, and much of it is slushed out into the ditches, and taken up with the ditching machines, and all that sort of thing.

I think it would be a proper work of this Committee to establish some measure or determination of the life of ballast. I am not sure that the life of ballast, by and large, would much exceed the life of the rail. In your address, Mr. President, you said that the figures of the notebooks did not always tell the story, and it may not be possible to work out an academic formula that would express this thing; but I think some idea could be conveyed as to the percentage of ballast in the track which disappears; and it disappears as the track becomes filled up with dirt, or is blown away or pounded down into the embankment. Moreover, the ballast that was put in 10 or 15 years before may have become of very little utility, as ballast, and there might be some way of determining approximately what percentage of the ballast which was put in when the road was built and which has been renewed from time to time is really effective as ballast at some later period.

Mr. Sattley:—Most of the railroads here represented have probably been valued. The Interstate Commerce Commission therefore knows pretty well how much ballast you have. They inspect every thousand feet of track alternately—first on one side and then on the other, and ascertain the kind of ballast and its depth. There are places where you have deep ballast, but it is in fills which have settled down. On our railroad we are perfectly satisfied with what the Government has allowed us for ballast and ballast material.

Originally they allowed us a foot of ballast under the ties, below the bottom of the ties. Later, on some districts it was made 24 inches under the tie. If it is a matter of 12 in. of ballast under the ties, they will allow that, but if you claim 24 in. under the ties, you have got to show

where that ballast came from, and the matter of knowing where the ballast comes from, and having a proper record covering that item, would mean thousands of dollars to many of the railroads in the country.

Mr. R. H. Ford (Chicago, Rock Island & Pacific) :—A great deal of good could be accomplished by this Committee if arrangements were made such that it could give some attention to a comprehensive study of the several divisions of railroad reports from the standpoint of simplification, standardization and unification of the endless reports which have been gradually accumulating for years on railroads. They could do more real, constructive good rather than to add to these by specifying some particular form of accounting or what some particular item of accounting should mean.

(Motion to receive the report as information carried.)

The President:—The Committee is excused with the thanks of the Association.

DISCUSSION ON RULES AND ORGANIZATION

(For Report, see pp. 749-751.)

Mr. W. H. Rupp (Oakland Terminal):—Mr. President and Gentlemen: I am from the Coast and was not able to attend the meetings of the Committee, being so far away. Chairman Finley was called to New York yesterday by wire.

The subjects assigned to the Committee will be found on page 749 of Bulletin No. 215.

The Committee decided to make no recommendation in regard to the first item, on account of the large number of rules and regulations being put into effect on account of Federal control. They are being changed every day, almost; in fact, by wire. On Subject 2 we have made a little progress. The item has been very briefly studied this year, because of the fact we are not constructing many new lines, and they are limited.

As to Subject 3, we report progress.

In connection with Subject 3, we present a monograph by Mr. John D. Rockefeller, Jr., on the "Science of Organization," which we believe will be interesting to our members.

We have done a large amount of work on Subject 4, but it is not in shape to present as a report. We think it should be gone over more thoroughly, and these various items should be reassigned to the Committee.

On Subject 5, with regard to the matter of fire protection, you probably know the Government has taken over the insurance of the property, and put the fire risk and the operation of maintenance of all buildings for the prevention of fire on a different plane from what they were under the old management, and the large force of inspectors put out by the Government has made the rules for this particular department. This matter is in a state of transition, as the rules are changing from time to time, and we think that this subject should also be reassigned. There was an important meeting in Chicago yesterday of the Chief Fire Inspectors of the Western Central District, and I do not know what rules the railroads will have when these inspectors go back to work, but it is a big item, since the Government is carrying its own insurance.

Subject 6, "Prepare Rules for the inspection of bridges and culverts," is a very broad subject, because every road has its own organization in regard to the inspection of bridges and buildings, and it can be handled in so many different ways by so many different railroads, and it is hard to define a set of rules that would cover the entire subject and we recommend that you reassign these subjects for another year and we will report progress on the subject.

I move that this report be accepted as a progress report and the subjects reassigned to the Committee.

(Motion carried.)

The President:—The Committee is excused with our thanks.

DISCUSSION ON ECONOMICS OF RAILWAY LABOR

(For Report, see pp. 756-802.)

Mr. E. R. Lewis (Duluth, South Shore & Atlantic) :—Your Committee was instructed first to report on "Plans and methods for organizing to obtain labor for railways." Last year there were reported, page 1124 of the Proceedings, in a discussion, three resolutions which are practically accepted to-day as the sense of the Committee upon this subject. The Committee reports progress on this subject.

(Mr. Lewis then presented the matter "On methods of equating track sections," Subject 2, on page 757.)

(Vice-President Stimson in the Chair.)

Mr. W. H. Courtenay (Louisville & Nashville) :—It seems to me an improvement on the method suggested by the Committee is to assign a given number of men to the Operating Division, and let the Roadmaster exercise his discretion as to where they should be working. There may be one section where less men are required than another, and their distribution should be left to his discretion, instead of telling him arbitrarily to put 1 or 1½ or 2 men on each mile. Give him the number of men for the whole division, and let him distribute the men as he pleases. This would be a practical and intelligent solution of that problem.

Mr. Lewis :—The practice of giving the Roadmaster a little latitude in that matter, I think, has obtained for a good many years on a large number of roads. Probably most of them have put it up to the judgment of the Roadmaster. Now, his judgment may be particularly good, or it may not be quite so good, and it has been found that in a great many instances proper results are not obtained. When the Committee on Track first started this subject, the idea was to reduce the subject to a science, which I thing it should and can be.

Mr. E. T. Howson (Railway Age) :—I will say further in reference to the point raised by Mr. Courtenay, that the Committee had this in mind. The Sub-Committee working on this subject endeavored to assist the Roadmaster by studying the effect of the various physical conditions of his track, the number of turnouts, etc., giving him the benefit of that data, so that he could distribute the force allotted to him between the different sections to more nearly equate the number of men to the work to be performed.

Mr. Courtenay :—In answer to that, Mr. Howson, I beg to state that we have prepared data very similar to that given in the report, that is, the equivalent work on main track, sidetrack, switches, tunnels, crossings, and various items of work of that kind that they have, but they are not arbitrarily bound by it. We give them a measure of discretion.

Mr. Lewis :—The Committee would be glad to have those rules that you have mentioned.

Mr. Courtenay :—We will be glad to send them to you.

Vice-President Stimson :—While this equation the Committee has

given is a guide, it cannot always be followed in the distribution of the force that is furnished. The actual condition of the track to be maintained is really quite a vital determining feature, that is, in connection with this equation, so in addition to this factor of equivalent mileage there is certainly what might be called condition per cent. that ought to come in in determining the proper distribution of the force.

Mr. C. C. Cook, of the Baltimore & Ohio Railroad, took quite a prominent part in working up the system that we had in effect for some years on that road, and developed this particular feature. I am sure we would be glad to hear from him with respect to it.

Mr. C. C. Cook (Baltimore & Ohio) :—The point brought out by Mr. Stimson is essential. There should be a condition per cent. If your condition on every section was the same to begin with, your equated mileage would be a proper basis, but that, of course, they do not have, so in figuring up the amount of force that each section should have it is necessary to take into account the condition of each section. On the Philadelphia Division we attempted this scheme and we found that in rating various sections we would, I recall, give as high as 90 per cent. as the condition on one section, and on some of the sections as low as 50 per cent., so you can see there would be quite a difference in the force allotted to those various sections. But the theory of it is essential, and I think, as the Chairman suggests, that it can be scientifically worked out, and it only means a very close and detailed study of the actual track and structure conditions. I do not think we can say that we could establish it to the fraction of a per cent., but in working out the detail for certain conditions per cent., and taking the sum of the whole, we arrive at a better conclusion than by simply arbitrarily fixing a force for the Roadmaster, or for each section gang. I think it is a subject that deserves more attention and more detailed study.

Mr. W. M. Camp (Railway Review) :—I do not think that the Roadmasters, or any other officials who come more nearly in contact with the track than perhaps a majority of this audience, will find any fault with this Association for working out a report on equating track sections. This has been a very practical question with the Roadmasters for a good many years, and if one looks through the Proceedings of the Roadmasters' Association for thirty years back, he will find that they were working at this question then. For instance, they were discussing the question of how many switches were equivalent to a mile of track, on a maintenance basis; or how many road crossings, or what amount of fence repairs amounted to the same thing.

In fact, this question has frequently been put up to the Roadmaster from underneath, in distributing his men over the sections. A foreman might come to him and say: "Look here; I have got no more men than the foreman whose section adjoins mine, and I have many more switches in charge than he has; and much more of this kind of work or another kind of work." So this is, I think, a very practical study for this Asso-

ciation to make. I feel certain that the Roadmasters would be gratified to know that such studies were being made by the Engineering Department.

I do not think it is intended that these methods of equating should be considered an exact guide in distributing men. There are many rules and principles to be formulated in reference to maintenance of way work that are useful if they can only serve as rough guides.

Mr. Lewis:—I want to say what has been said, I think, in this Committee before, that it is not intended—it is not possible probably—to give you percentages that would be applicable to more than one road. This is a problem that every man must work out for himself, taking into consideration the peculiar factors on his own road. Furthermore, percentages will vary from year to year to some extent. This has been a very mild winter, and you have had less expense for removal of snow and ice than usual. Percentages will vary on the different divisions of one railroad. There are many indeterminate factors, and it does take considerable work, because you have to take twelve months' results before you can get complete and proper data for calculation. The Committee has given percentages here that may be exact on some roads, while for other roads they might not apply at all, probably would not. It is a question that each Engineer must work out for his own road.

Mr. C. W. Baldridge (Santa Fe):—It has been my own experience in handling track that this equating of track values is something which every Roadmaster must do, and he ought to find some rule other than his own judgment to guide him. An outline of this kind would unquestionably be a great advantage, especially to a man while he is new at the game. I think it is an excellent plan.

Mr. Lewis:—The Committee feels that it has done its duty in bringing this matter before the Association. The Committee recommends that this report on the method of equating track sections be accepted as information and printed in the Proceedings.

(Motion carried.)

(Mr. Lewis then presented the matter "Typical plans for housing labor," Subject 3, on page 763.)

Vice-President Stimson:—This part of the report is offered for criticism. I think most of us have our own ideas with reference to this subject, and we will be glad to have some expression.

Mr. J. L. Campbell (El Paso & Southwestern):—This phase of the subject suggests an element of the problem lying somewhat outside of or beyond the obvious field of physical activity and the solution of the physical problems involved in maintenance and operation of railways. Indeed the solution of the merely physical problems and the work of applying the solution to the upkeep of the property are the simple elements of the larger problem.

Quite apart from the field of physical problems, solutions and activities there is another field that will, I am sure, if comprehended and occupied reasonably well by this Association and its members, add greatly to

the value of the Association and its members in their service of maintaining and operating railways.

This Association and its members are doing very well indeed in the solution of the physical problems of their task, but the laborer directed by them in so doing is much more than a mere physical machine. Physical results are, of course, primarily required of us. But when we take up the question of the housing of these employes we come at once face to face with the human element. Whether or not we recognize it and whether or not we are prepared to admit that which is before us, we then have to deal with that wonderful element, the human heart, with all of its longings and its aspirations, noble or ignoble. So, I anticipate, we are coming to a point where that element of the problem will enter much more extensively into our consideration. In the question of the economics of railway labor, the human heart is inevitably involved.

These trackmen who are out on the track working there in the cold of winter and the heat of summer and whom we salute as we ride by are men like ourselves. They have longings, aspirations and ambitions from which have arisen the problems of capital and labor. In as far as we comprehend the human element; in as far as we handle and cultivate it aright; in as far as we properly and legitimately satisfy the human heart, we are solving to the advantage of all the most vital element of the problem and building an esprit de corps, thereby bringing to any organization a wonderful strength and help in working out the merely physical problems and getting physical results. In as far as we as employers and employes, as directors of work and as those who obey directions get together as human beings on common ground of understanding, the better will be our solution of the really great problem before us.

The most vital problem before the Association, its members and the transportation business is not a physical problem. It is rather the right adjustment, as nearly as may be, of the human factor, bringing all together on a common foundation of sympathetic understanding and recognition of and observance of the welfare of each individual resulting in harmonious co-operation to ends mutually beneficial.

We are, of course, not going to attain all that in a day. I do not know that attainment will ever be complete. That phase of the future is somewhat obscure to me and, I presume, it is to you. But regardless of what we now think of it, of our preparation or lack of preparation to meet it, there it is—the great problem of the future.

But we can make a little beginning here in the matter of the housing of these employes, in the treatment we give to them, in the human touch we bring to them. To the extent that we do that aright, we are contributing something to the solution of the problem. The war has developed this problem to an acute stage and we must, regardless of the conditions of the past, recognize that we do not stand to-day where we stood yesterday. It is becoming more and more acute every day and I believe it will be wise and profitable to this Association, its members, the transportation

business and our country to think seriously about these things, as I have no doubt you are thinking, because in the common thought of our civilization there will be found finally, perhaps, the right solution. (Applause).

Vice-President Stimson:—I thing the manifestation of this human interest is shown in the designs that have been presented for providing the men with decent places to live in, and the Committee has certainly provided some very satisfactory and adequate means to serve this end.

Mr. R. H. Ford (Chicago, Rock Island & Pacific):—During the past year the railroads have gone from the 10 to the 8-hour day for track and other labor. Entirely new problems of working conditions have now become of paramount importance and these have been further complicated because of the wage increases. The result has been to introduce entirely new factors in maintenance of way labor on railroads. The ratio of efficiency for track labor has been for years much lower than in almost every other line of industry, and one of the principal contributing factors has been the wretched housing and feeding conditions which railroads have in the past permitted to continue. As a matter of simple business more attention will have to be paid to this and other associated problems. The average railroad man has little conception of the comparison in the care of labor between industrial concerns and the railroads generally. The efficiency of extra gang labor is as low as 31 per cent., which means that the expenditure is about three times what it ought to be for the work obtained. These comparisons, when checked with the efficiency of labor performed for contractors and industrial concerns, is one of the reasons why it costs so much in total to obtain so little in result. In order to obtain a greater degree of economy in expenditure improved methods and modern principles will have to be better understood by railroad men generally and railroad labor better cared for, better housed, better fed and some plan be worked out whereby there will be more uniformity of employment if better results are to be obtained.

Mr. Lewis:—The Committee recommends that this report on typical plans for housing labor be received as a progress report.

Vice-President Stimson:—If there is no objection, it will be so received.

Mr. Lewis:—We present Appendices C and D as progress reports, and desire their reassignment for further consideration.

Vice-President Stimson:—If there is no objection, that will be the course taken. If there is no further discussion, the Committee will be excused with the thanks of the Association.

DISCUSSION ON WOOD PRESERVATION

(For Report, see pp. 119-158.)

(Vice-President Stimson in the Chair.)

Mr. C. M. Taylor (Philadelphia & Reading and Central Railroad of New Jersey):—The report of the Committee on Wood Preservation is rather long, and it is not expected that you will want it read. It was published in time for everyone to get a copy of it, and as we go over the report, if there is any point that any member wishes discussed more thoroughly than it is given in the report, we will be glad to have it discussed.

The particular work before the Committee this year was the revision of the creosote oil standards up to the present time, and we have given you in the revised specifications as shown in Appendix A, under the "Revision of Manual," the new specifications for creosote oil as we feel should now be in force. They are the result of co-operation with the American Wood Preservers' Association and the American Society for Testing Materials. So far as the basic changes in the old specifications as now appearing in the Manual, they are not very great, but you will note in each grade of oil we have added the underscored portions as shown on pages 122, 123 and 124. Those are the additions that we have made to the present specifications, particularly Section 5, in each specification for creosote oil, covering a new refinement for determining the purity of oil, which says that: "The specific gravity of the fraction between 235 degrees Centigrade and 315 degrees Centigrade shall not be less than" a certain gravity. That is a clause that has been added in order to tie down the high boiling point fractions. Further, there has been added the process given under Section 6, of each specification. This is another guarding point to take care of high boiling point fractions. Likewise, Section 7 of each specification. These specifications are proposed for adoption and publication in the Manual, and, Mr. Chairman, I therefore move you that the revised specifications for grades 1, 2 and 3 of creosote oil, as underscored on pages 122, 123 and 124, be adopted for publication in the Manual.

Mr. J. L. Campbell (El Paso & Southwestern):—Has the Committee conferred with manufacturers of creosote and ascertained that there will not be material difficulty or objection to compliance with the specification? I have no doubt the specifications are what they ought to be and that the Association should occupy the position that specifications right and reasonable should be complied with, but, I dare say, the general experience of the members of the Association not infrequently comes into contact with strenuous objection of manufacturers to furnishing material according to specification on the ground that the specification should not be fully complied with for various reasons set up by them.

Mr. Taylor:—We hope the war is over, and we submit this as a peace-time specification, and the manufacturers assure us there is no reason why these specifications given here cannot be followed. There is no

reason why you cannot buy oil according to these specifications at reasonable prices.

Vice-President Stimson:—I ask the Committee if these specifications as revised are the same as adopted by the American Wood Preservers' Association?

Mr. Taylor:—They are the same as proposed for adoption by the American Wood Preservers' Association, so the two associations are proposing to have exactly the same specifications, so that we will have one specification under which people may work, and they will both be the same if they are adopted by both associations.

Vice-President Stimson:—The American Wood Preservers' Association, I believe, had a meeting in January. Were these specifications submitted and acted upon at that time?

Mr. Taylor:—The ballots of the American Wood Preservers' Association vote on this subject have not all been counted, so that, while we feel these specifications will be approved by that association, we cannot guarantee it.

Vice-President Stimson:—I do not believe an important matter, such as changing the specifications which have been in force for a number of years, should be passed without some discussion.

Mr. C. E. Lindsay (United States Railroad Administration):—On page 124 the following statement appears: "It is urged that when grades 2 or 3 are used, consideration be given to the injection of a greater quantity of creosote oil per cubic foot." Can the Committee give us any information as to what increased quantity should be used for the particular grades in question?

Mr. Taylor:—The Committee is not prepared to propose any standard for the further clearing of that clause, because when you use grades 2 and 3 you are not using the best grades of creosote oil; consequently, what one might consider a factor of safety in using 1 or 2 lb. more per cu. ft., might not appeal to another Engineer, so that we have left that open.

The clause was inserted there to help anyone to get more oil per cu. ft., if he could not obtain grade 1, which has been the condition this last year, and possibly always will be the condition. We always expect that more than one grade of creosote oil will be offered, and no Engineer can expect, with any assurance, that he will get the same results from grade 3, the same quantity being used, as he will get from grade 1. It is similar to the amount of wear you will get out of an 80-lb. rail compared with a 100-lb. rail.

(Mr. Taylor's motion carried.)

Mr. Taylor:—The next specification is on page 124, "Specifications for creosote-coal-tar solution." That is the oil that is being used in probably 95 per cent. of the work at the present time. It is a mixture of coal tar and creosote, and is called creosote-coal-tar solution. The specification for it exists in the Manual as shown up to Section 5. We are safeguard-

ing that specification a little further by adding Sections 5, 6 and 7, so that the additions to this specification are the same additions we have made in connection with grades 1, 2 and 3, and were put there to help get a good creosote-coal-tar solution.

I move that that portion of the specifications for creosote-coal-tar solution, as given in Sections 5, 6 and 7, on page 124, be approved and published in the Manual.

Mr. Lindsay:—I would like to call attention to the use of the word "standard" in the last paragraph on page 124. There is no standard in the American Railway Engineering Association.

Mr. Taylor:—The distillation method has been standardized by the Association.

Mr. Lindsay:—Recommended practice?

Mr. Taylor:—Recommended practice. We will be glad to make that correction.

Mr. W. H. Courtenay (Louisville & Nashville):—As a matter of information I would like to ask of the Committee if there is any known way of ascertaining whether the purchaser gets a distillate or a mixture of a distillate of coal tar with crude coal tar? In our own practice we have been unable to ascertain that. A good deal of oil appears to be a mixture, and the seller denies it is a mixture, and claims it is all a distillate of coal tar. Is there any way of determining whether there is any undistilled coal tar in the product furnished?

Mr. Taylor:—In answer to that would say that on page 125 we have endeavored to give you six precautions that should be followed in the purchase of creosote-coal-tar solution, which will come up in a few minutes and will cover that point.

Mr. Courtenay:—I do not think that covers it. Suppose a producer wants to defraud a purchaser, how is the purchaser going to find out whether he got a mixture or not?

Mr. Taylor:—Creosote oil is an organic mixture consisting of many different compounds. It is quite a complex problem. If a man has attempted to make a good coal tar solution, there will probably be times when you will not be able to tell whether he added refined coal tar to that mixture or not, and a good creosote-coal-tar solution is a good oil, and if it fulfills these specifications we believe it to be a good preservative for most purposes. As to its composition, we are not always able to determine if we were not present at the time of manufacture, and it is for that reason that we have suggested these six precautions. An analogy will probably be cast-iron castings. The situation is almost the same. When you get finished cast-iron castings you have reason to believe that possibly there is some poor scrap used in it, but, if it fulfills the specification, the manufacturer presumably has done what you expect of him.

(Mr. Taylor's motion carried.)

Mr. Taylor:—The next is on page 125: "Precautions to be followed in the purchase and use of the creosote-coal-tar solution." These pre-

cautions are given in a revised form to take care of just those people who want to be reasonably certain that they are getting a good creosote-coal-tar mixture. You really have to be present at the mixing to analyze the tar and the creosote oil to be sure that the manufacturer is doing what you want. It is for that reason that we suggest the adoption of the revised precautions on page 125. I move their adoption for publication in the Manual.

(Mr. Taylor's motion carried.)

Mr. Taylor:—The Association has already adopted for recommended practice the methods for actually determining the absorption of creosote oil. That same method applies to determining creosote-coal-tar solution. We would, therefore, recommend as shown on page 126, the paragraph underneath the cut, that the heading in the Manual which covers the point of "Methods of Accurately Determining the Absorption of Creosote Oil" be changed to read: "Methods of Accurately Determining the Absorption of Creosote Oil and Creosote-Coal-Tar Solution."

They are both measured in exactly the same way, and the practice as already recommended for creosote oil should be enlarged to include the creosote-coal-tar solution.

I move that that heading be changed to read as shown.

(Motion carried.)

Mr. Taylor:—As changes have taken place in the manufacture of creosote oil in the last few years, it has been necessary to add extra instructions in the actual analysis of creosote oil, and under the heading of "Analysis of Creosote Oils," starting on page 126 and ending on the middle of page 132, you will note considerable underscored matter covering refinements in connection with the analysis of creosote oil. They are in line with the work done in conjunction with a similar committee of the American Society for Testing Materials. They are purely chemical additions to standardize among all operators the analysis of creosote oil. This covers the additions to the specifications as already approved at this meeting, covering the float tests and coke residue as explained on page 131. If there are any questions in connection with these additions to the chemical procedure, we will be glad to explain them further.

I move you, Mr. Chairman, that the underscored portions under the heading "Analysis of Creosote Oil,' as given on pages 127, 128, 129, 130, and 131, and up to the middle of page 132, be adopted for publication in the Manual.

Mr. Lindsay:—I would like to again call attention to the misuse of the word "standard" on pages 126 and 127.

Mr. Taylor:—We will be glad to make that correction.

(The motion by Mr. Taylor was adopted.)

Mr. Taylor:—The next point is the "Standard Specification for Zinc Chloride." Any of you who have been in timber preservation this last year know that zinc chloride is largely used as a preservative, and we have revised these specifications to meet the present-day conditions, and

the future conditions, and they are shown on page 132. The specification is short, but it covers everything that we need to have in connection with a specification for zinc chloride at the present time. I move you that it be adopted for insertion in the Manual.

(Motion carried.)

Mr. Taylor:—Particularly since the Government has been controlling the practice at the different treating plants, it has been found necessary to devise a new method for determining the strength of zinc chloride solutions as they are used in the different plants, and it is for this reason that the Committee is proposing for adoption the method as shown on page 133. It is a chemical method, and it has been in use long enough to prove that it is very reliable. The old hydrometer scheme is not good practice because of the fact that most zinc chloride solutions have some creosote oil in them, and have a tendency to affect the Baumè readings, so that this method is proposed, and is now in actual use, in the majority of our Government-controlled treating plants.

Mr. Chairman, I move its adoption for publication in the Manual.

(Motion carried.)

Mr. Taylor:—I want to call the particular attention of all the members to our report on zinc chloride treatment. As Chairman of the Committee, I feel proud of it, and I would dislike to go away from the meeting without bringing to your attention particularly our report, which starts on page 137, covering zinc chloride treatment. We were directed to make a critical study of the records of service given by the zinc chloride treatment, and to state definitely the results which may be obtained from that treatment.

We had a Sub-Committee composed of Messrs. Rex (chairman), Howard, von Schrenk and Waterman. They went into the subject of zinc chloride treatment very fully, and their report is given on pages 137 to 156. It is the best report on zinc chloride treatment that has come out for years, and they have gone into the matter very thoroughly, and anyone who is at all interested in this subject can well afford to spend a few minutes in reading just what they have given you.

In connection with their report, they have, on page 147, proposed "Specifications for the Treatment of Ties by Burnettizing Process," which process uses zinc chloride. This specification is now in use in the Government-controlled treating plants for the treatment of cross-ties. It has been in service long enough to make us feel perfectly sure that it is a specification which we can all adhere to.

I move the adoption of the specifications for the treatment of ties by the Burnettizing Process, as underlined on pages 147, 148 and 149.

(Motion carried.)

Mr. Taylor:—That covers everything we have recommended for adoption, and the Committee appreciates your accepting our recommendations.

In connection with this report on zinc chloride treatment, the Com-

mittee went into the discussion of it primarily from a war standpoint, because it was a preservative that was available in large quantities throughout the war, and they came to the conclusion that, due to the scarcity of creosote oil, there were certain territories where at that time it was not advisable to use anything but creosote oil if it was available, and in the other parts of the country they should use zinc chloride, and you will note between pages 150 and 151 there is a map of the United States showing the line of demarcation between the territories that should use the zinc chloride and those which should use the creosote oil. The line follows very closely the 40-in. rainfall. It starts in on the Gulf Coast in Texas and reaches the Canadian border at a point very close to Maine. That line is one that possibly by future Committees will be advanced further north and further west, and coincide with what has been the line previously between the roads that use zinc chloride and those that use creosote. In connection with this study they found that there were three general conclusions that should guide any railroad in determining what treatment should be used in its particular locality. You will find these on page 150 under the heading "General Conclusions." These are submitted to you for your information, and we do not ask for their adoption. They are sign-posts for Engineers who are considering the adoption of any of these preservatives. The basis for these conclusions is largely drawn from the records given on page 157. There is nothing new about this indicator for determining the penetration of zinc chloride in timbers, except that we have taken what has been done by the Forest Service, and improved it some. Mr. Bateman, who is with the Forest Service, published a circular entitled "A Visual Method for Determining the Penetration of Inorganic Salts in Treated Wood." That method has been used by most operators, but the line of demarcation between the treated and untreated wood was not clear, and this Sub-Committee has investigated this subject and has given you a method that is clean and concise and will give the results you are asking for.

Just to show you what it is, we have had a zinc chloride treated tie cut in half and colored to show the penetration as brought out by this new method proposed by the Committee. That is a longleaf sap pine tie (exhibit, section of tie) and was treated with ½ lb. of zinc chloride per cu. ft. You will notice it is approximately 85 per cent. heart, and the red area in the center is the untreated area. All the white area is that area which has been treated, and the line of demarcation is very clear, much clearer than was brought out in the old method. I will leave this on the table and you may examine it.

Vice-President Stimson:—The Committee is excused with the thanks of the Association for its excellent report.

DISCUSSION ON YARDS AND TERMINALS

(For Report, see pp. 411-430.)

(Vice-President Stimson in the Chair.)

Mr. B. H. Mann (Missouri Pacific):—The subject of "Unit Operation of Railroad Terminals in Large Cities" has been included in approximately 150 questions under about 57 subheads. It has been suggested that we include in this year's Proceedings a skelton of a sample organization of a unified terminal, and so that the Association may intelligently pass upon including those in the Proceedings, I will ask Mr. H. J. Pfeifer, Chief Engineer of the St. Louis-East St. Louis Terminal District, to read the skeleton that is proposed to be included, which has been issued covering that district.

Mr. H. J. Pfeifer (St. Louis-East St. Louis Terminal District):—I was asked to present the basis of the organization of the Terminal District at St. Louis, and I thought that the best way to do so would be to read the circulars issued by Regional Director Bush, announcing the appointment of A. S. Johnson as Terminal Manager, dated July 9, 1918:

"The appointment of Mr. A. S. Johnson as Terminal Manager of the St. Louis-East St. Louis Terminal District, effective this date, is hereby announced.

The Terminal Manager will have direct charge of the Terminal Railroad Association of St. Louis, including: St. Louis Merchant's Bridge Terminal Railway, Wiggins Ferry, St. Louis Transfer Railway, East St. Louis Connecting Railway, Interstate Car Transfer, East St. Louis Belt Railroad, Granite City and Madison Belt Line, Tunnel Railroad of St. Louis, East St. Louis & Carondelet Railway, St. Louis Belt & Terminal Railway, St. Louis Bridge, St. Louis Terminal Railway, Terminal Railroad of East St. Louis, Union Depot of St. Louis, Illinois Transfer Railroad, St. Louis Merchant's Bridge, Union Railway & Transit Company of Illinois, East St. Louis National Stock Yards, St. Louis National Stock Yards, St. Louis and O'Fallon Railway, Alton & Southern Railroad, East St. Louis & Suburban Railway, St. Louis & Belleville Electric Railway, Litchfield & Madison Railway, St. Louis, Troy & Eastern Railroad, and will have jurisdiction over the terminals of all lines within the switching limits of St. Louis-East St. Louis District, reporting to the Regional Director of the Southwestern Region."

Also, a supplemental circular issued by Regional Director Bush, dated July 10, 1918:

"As announced in circular appointing Mr. A. S. Johnson Terminal Manager of the St. Louis-East St. Louis Terminal District, effective July 9th, 1918, he will have jurisdiction over the terminals of all lines within the switching limits of the district.

"The local or division officers of road lines who now exercise supervision over road division terminals in the St. Louis-East St. Louis switching district will continue such supervision as heretofore, furnishing the Terminal Manager such reports as he may request from time to time.

"When there is necessity, the Terminal Manager will issue instructions direct to these local or division officers, who will be governed accordingly.

"If, at any time, compliance with Terminal Manager's instructions is in conflict with other instructions which they may receive, the local or

division officers will immediately notify the Terminal Manager, who will then communicate with the Federal Manager, or General Manager, of the road interested."

I might add in explanation that the railroads, other than the Terminal Railroad Association of St. Louis and its affiliated lines, placed under direct control of the Terminal Manager, include the railroad facilities of the St. Louis National Stock Yards, the Alton & Southern Railroad, which is a belt line around East St. Louis, and five short coal railroads in Illinois, that extend out of East St. Louis a maximum of 43.4 miles. These roads bring in a very large percentage of the coal used in the St. Louis territory.

Mr. Mann:—It is proposed to add as well a skeleton of the Seattle terminal, which Mr. Aishton advises is the one terminal in the Northwestern Region in which all facilities are placed under one man. It is the ambition of the Committee to be of use as a means of exchanging experiences as to unification, and discussion will be of great help.

I move that Conclusion No. 1, on page 153, be adopted.

Mr. C. E. Lindsay (U. S. R. A.):—It is a little unusual to publish something in the Manual that we have not seen, and while I am heartily in accord with and approve of the work that has been done by this Committee, I question very much the advisability of that method.

Mr. Mann:—The Committee would like to state that the inclusion of the skeleton of the organization of a representative terminal which has been requested would not be a matter of recommended practice in any way under the control of this Association, but it would merely mean a question showing what has been put in effect by the Railroad Administration. It would be a matter of history, which should be included in the Proceedings of this year to complete this report.

Mr. Lindsay:—Mr. Chairman, it would be of much greater benefit to the Association in the Proceedings than it would in the Manual for next year. A great many more people would be liable to see that if it was published in the Proceedings than if it was deferred until it could be published in the Supplement to the Manual, which will not be out until late in the year.

Mr. C. W. Baldridge (Santa Fe):—Inasmuch as the Manual of this Society is intended to represent recommended practice, also that the skeleton organization has not been printed for information, or in such manner that we could study it, it seems to me it would be proper to permit this entire matter to remain in the Proceedings for this year, and call it up for consideration or adoption and publication in the Manual next year, as has been done with a number of other cases, both last year and this year. If I may be allowed, I move as an amendment to the motion that this entire matter be deferred until next year, or be carried in the Proceedings until next year, and then submitted for adoption for the Manual.

Mr. Mann:—In explanation I would say, request has been made that this be included in the outline that is to go out in the literature this

year. As far as the Committee are concerned, they wish to abide entirely by the wish of the Association.

Mr. Baldridge:—That information will be available in its present form in the Proceedings, and inasmuch as you think the skeleton form ought to be included with what you have given, no harm can be done by carrying it over until next year, so that it may then be put in as a unit, if, after further consideration, the Association desires to do so.

Mr. W. M. Camp (Railway Review):—As I understand it, the matter which is submitted here has been pretty carefully considered, and unless it is the expectation that it shall be revised, I would think it proper to put that portion of it in the Manual. One way to get around this matter which has not been printed, I should think, would be to insert the printed matter in the Manual, with a reference note to the effect that these skeletons which have not been published, and which, as I understand, are matters of local concern, can be found in the Proceedings.

Mr. John V. Hanna (Kansas City Terminal):—It seems to me, in view of the situation in which the railroads find themselves to-day, that it is a little early to put anything in the Manual on this subject of unit operation. The question is under consideration of turning the railroads back to their owners, and this whole subject may be a good deal modified by that action. The Committee's report is available as information to everybody who is interested, because it is in the Proceedings.

Mr. L. S. Rose (Cleveland, Cincinnati, Chicago & St. Louis):—Mr. Chairman, will you please have the Committee state just what they want to put in the Manual?

Mr. Mann:—The matter covered by Conclusion No. 1, which begins at the top of page 161, and runs down to about the middle of page 172, to the line, "Subjects Nos. 3-4."

Mr. Rose:—It seems to me these questions are not fit subjects for the Manual. It seems to me this Catechism is not a fit subject for the Manual—a list of questions asking whether we are operating unit terminals, and all that sort of information.

Mr. Mann:—The Committee would like to explain that last year the Catechism on Design and Operation of Yards and Terminals was handled in this way, and this is merely proposed, following along that experience and sequence.

Mr. Rose:—I think the Catechism is all right to find out something, and after we get the information, we can set up a standard. I would not make the Catechism a standard. This is a temporary arrangement. Nobody knows yet whether these tracks and terminal yards are economical or not. They have not tested them out. I think it would be better to wait until we find out where we are going.

Mr. J. L. Campbell (El Paso & Southwestern):—Mr. President, I believe a principal objection to inclusion of this matter in the Manual at this time is the immature state of it. It is in process of development. Much may come out of it. In a year or two we may be able to arrive at

conclusions sufficiently conclusive to warrant entry into the Manual. I believe the knowledge of the Association in the matter is sufficiently incomplete to warrant deferring inclusion in the Manual for at least one year.

Vice-President Stimson:—For the information of the members present, I would state that the Catechism of Yard Design and Operation was adopted last year and printed in the Supplement to the Manual, Bulletin 207. The matter is very similar to what is now offered for adoption.

Mr. Baldridge:—In comparing the Catechism which was adopted last year with that offered this year, I think you will find the Catechism adopted last year was on yard design, which is pretty definitely established. The Catechism this year is dealing with a subject which is not yet established, and another year may make a great deal of difference in what is required. It seems to me better to leave this in the Proceedings for a year, and we can take the matter up again next year.

Mr. H. S. Balliet (Grand Central Terminal):—If it is in order, I move an amendment to the motion that the matter be received as information, supplementing information or recommended standards printed in the Supplement to the Manual last year, on the basis that this is a development or carrying through of a scheme which will be the ultimate matter to be placed in the Manual.

Vice-President Stimson:—The Chairman of the Committee has offered to withdraw his motion, and to have it printed regularly in the Proceedings. I think that satisfies the point raised.

Mr. Pfeifer:—It seems to me that the adoption of this report for insertion in the Manual does not necessarily mean that this organization goes on record in favor of the policy of unified terminals, but that in the consideration of the problem the points raised in the Catechism must be given due weight.

Mr. Hanna:—I think the Committee is to be commended for the work they have done along this line. It is excellent. I have read the report with a good deal of care, and I think it is well to show some appreciation of what they have done. I do not think, however, that it is quite time to put it in the Manual.

Mr. Mann:—The Committee wishes to change the motion so that it shall read that this matter outlined in Conclusion No. 1 be received as information and printed in the Proceedings.

Vice-President Stimson:—The Chairman calls attention to the fact that while there was considerable discussion, none of it was on the subject-matter of the report, but rather on the disposition to be made of it, so the Chair takes the liberty of opening up the question again for discussion of the subject-matter of the report..

Mr. Balliet:—I am very much interested, and I would suggest to the Committee, if it is along that line of work, which I hope it is, that next year's Proceedings, so far as consistent and possible, give us diagrams, not necessarily diagramatic, but maybe in word form, of all of the ter-

minal organizations. It will give us a very fine start towards bringing this very important matter to a satisfactory conclusion. From my point of view, without a full knowledge or careful study of the makeup of the units and the conditions generally involved, it is a very much involved subject. I can state from my own personal observation it is important that we work along that line, and in that way make considerable progress towards unification.

Mr. J. L. Campbell:—Mr. President, I believe the Committee can obtain some interesting information of the unification of the terminals at El Paso, Texas. The railroads entering there are completely organized in a unit terminal operation. It appears to be satisfactory to everyone, and I believe some decided economies have been attained.

Mr. Mann:—Subjects 3 and 4, the Committee makes no report this year to the Association.

(Mr. Mann here read portions of the report under Subjects Nos. 5-6.)

I move that the matter under Subjects 5 and 6 be received as a progress report.

(Motion carried.)

Mr. Mann:—The Committee wishes to call particular attention to the additional matters shown in Appendix A, Appendix B and Appendix C, which were included in the preliminary report, and then Appendix D and Appendix E, which is matter that has been given to the Committee since the preliminary report.

Vice-President Stimson:—The Committee has furnished the Association with a very valuable report. If there is no further discussion, the Committee is relieved with the thanks of the Association.

SPECIIFICATIONS FOR RAILRORD TRACK SCALES

Vice-President Stimson:—We will next take up the Supplemental Report of the Committee on Yards and Terminals. Mr. Mann will present the report.

Mr. B. H. Mann (Missouri Pacific):—The question to be considered is first a letter from President Morse to Secretary Fritch. It is as follows:

"I am handing you herewith a copy of the Specifications for Railroad Track Scales gotten out by a Committee appointed by Mr. Aishton, Regional Director of the Northwestern Region.

"Mr. Aishton suggested that the specifications be referred to the Committee of the American Railway Engineering Association on Track Scales.

"Mr. Tyler, Director of Operation, in handing me these specifications, says: 'Mr. Aishton's letter indicates that we should not delay the matter of approval very long on account of the situation in Minnesota, and I shall be glad if you will ask both Committees to go over the proposed specifications and advise in the premises without undue loss of time.'

"The other Committee to whom I am referring this set of specifications is the Committee on Weighing of the American Railroad Association. I would suggest that you hand these to the Chairman of the Committee on Track Scales at the Convention, and ask him if he cannot get his Committee together and go over these specifications and make at least a preliminary report during the week of the Convention."

Mr. Baldwin will read the preliminary report of this Committee. This is a report we have prepared, addressed to the Secretary of the Association.

Mr. Hadley Baldwin (Cleveland, Cincinnati, Chicago & St. Louis):—The report is as follows:

"Referring to attached papers enclosing specifications for new track scales submitted by Mr. Aishton's Committee. Your Committee states that it cannot, in the limited time at its disposal, make such a thorough study of these specifications as would make immediate approval thereof anything more than a merely perfunctory act. We may safely say that they are good specifications, according in their more essential provisions very substantially with our own specifications adopted one year ago. Nevertheless our cursory examination shows there are differences from our specifications which we think may well be brought in question and it sems to our Committee that in a matter of such wide and important application there ought to be time enough allowed for deliberate examination.

"We therefore recommend that the Secretary of the American Railway Engineering Association be directed to arrange for a meeting of the Committee on Weighing of the A. R. A. and the Track Scale of this Association, to be held not later than April 8, inviting Mr. Aishton to have his Committee represented at such meeting and that the A. R. E. A. Committee be given power to act under the direction of the Board of Direction of the A. R. E. A."

COMMITTEE ON YARDS AND TERMINALS.

Mr. Mann:—In explanation of the report, the Committee does not feel that the specifications of Mr. Aishton's Committee can be substituted for the specifications which we have in our Manual without some further study, and we ask this further time in which to make the report, as desired by the Railroad Administration.

Mr. C. E. Lindsay (U. S. R. A.):—I move the adoption of the recommendations.

Mr. George W. Kittredge (New York Central):—Can the Committee tell us in a general way the variations of this proposed specification from those already adopted by the Association?

Mr. Baldwin:—The Committee has made an informal reply to Mr. Aishton's representative, Mr. Haugh, his Engineering Assistant, but its criticism was made hurriedly and is tentative. We did not feel as positive of our criticism as if there had been time to deliberate and make a thorough comparison of these specifications with ours.

(Mr. Baldwin reads letter.)

These are some running comments we made, as stated, after a hasty study of these specifications. We did not attempt to make a final judgment and do not insist on standing by this criticism, but it is the result of our hasty examination of the specifications. If we are to make any further criticism than that we have made to the effect that they are generally good specifications, and accord closely with the substance of our specifications, we cannot do it to-day. Speaking for the Committee, we did not feel we had the time in which to do that.

Mr. Lindsay:—The American Railroad Association has been formed to give to the United States Railroad Administration prompt action on questions of this kind. This is the first action that has been asked of the Engineering Section of that Association and this Association has an opportunity to perform useful service. As in all cases, they want quick action, which sometimes means snap judgment; so that it seems to me we must be careful what action we take.

Are we referring this question to a Sub-Committee, with power to act, to take up the negotiations at the meeting on April 8th, and authorizing them to express the opinion of this Association on the subject, or are we authorizing that Committee merely to co-operate with the other men to the extent of giving them the benefit of their knowledge and their co-operation, and of studying and analyzing our specification as compared with the proposed specification? We should define just what authority our Committee has at that proposed meeting.

Mr. Mann:—The Committee discussed that question for a long time this afternoon. The Committee felt that this was the first opportunity for this Association to give this direct service to the Railroad Administration, and the thought of the Committee was somewhat along this line—that the situation had come up that in one region specifications had been submitted to the Administration at Washington, the Regional Director asking in the meanwhile that these specifications that have been submitted to Washington be referred to this Association for approval, and that the approval be not delayed any longer than was absolutely necessary.

The Director of Operation, in handling the matter, merely added one more committee to act and it is the thought of our Committee that it was the purpose of the Railroad Administration to say that when these two committees met and made their report on this specification that it should be final as far as the Railroad Administration was concerned. The Committee believe that is the case, due to the fact that the point is emphasized that we must have action without undue loss of time.

In discussing the rules and regulations the Committee saw no other way of getting formal action before next year.

Mr. Lindsay:—I think it would be desirable to instruct our Committee what to do when they get to the meeting, and I move an amendment to the pending motion that they be authorized to act in behalf of this Association. The exigency of putting into effect specifications for track scales, under the auspices of the United States Railroad Administration, is so great that when this Committee reports on common specifications, in which the main essentials are substantially the same as ours, there is nothing this Association can do, as I understand it, in influencing the Railroad Administration against proceeding to put them into effect.

Mr. Kittredge:—It seems to me that Mr. Lindsay's amendment is in order. If we instruct this Committee to act on behalf of the Association, all right; if the Committee finds all of the items in the specification agree with the items that are already in our Manual, why that is all right. But if there is a departure and the Committee feels they ought to yield in certain respects, they should be authorized by us to take action. They

should not change the Manual without being duly authorized so to do.

Mr. George H. Bremner (Interstate Commerce Commission):—It seems to me we should not give up the authority of this Association over the Committee. This Committee can have their joint meeting with instructions to arrive at their conclusions, and recommend these conclusions through the President of the Association, and the President can transmit these as Committee recommendations to the United States Railroad Administration at the meeting of the Association, so that they will still be subject to final review by this Association, but in the meantime they may be put into effect by the Railroad Administration. If the President thinks the conclusions such that they should not be handled in that way he can then submit the recommendations to the Board of Direction for approval.

Mr. J. L. Campbell (El Paso & Southwestern):—This Committee should be empowered to act for the Association, agreeing with other parties represented on a specification for scales. In lieu of that, the Committee could be authorized to act in an advisory capacity to the other parties recommending to the Railroad Administration specifications which, in its judgment, would be be all right for the Administration. The Administration desires specifications immediately; consequently the Committee should be empowered to act and have the specifications as nearly as possible in conformity to the specifications of this Association.

Mr. Baldwin:—We think we can come to agreement with their committee if there is reasonable time to discuss the matter. It was the feeling of our Committee that it should have a conference and by means thereof be enabled to make a definite report to this Association.

Mr. H. R. Safford (U. S. R. A.):—I think all we need to do is to authorize the Committee to meet the other committees specified and give them power to lend their endorsement to any specification that may be agreed upon between the three committees, provided it is understood to be merely a tentative specification and have it stipulated that it does not bear the final endorsement of the American Railway Engineering Association.

Mr. W. M. Camp (Railway Review):—Suppose that a specification for wood preservation or a specification for rails should be presented in a similar manner, and these committees unite with other committees and call it a tentative agreement; will not that have the effect of undoing the work of this Association to some extent?

Mr. John G. Sullivan (Canadian Pacific):—If there is nothing wrong with our specification, why does not this Association say so—that we recommend that they take our specification and have done with it.

Mr. W. H. Courtenay (Louisville & Nashville):—Has Mr. Aishton's Committee given consideration to the specification of this Association, and if so, what objection have they to it?

Mr. Baldwin:—I understand indirectly our specifications were considered and made the basis of their specifications. That is borne out by the fact that in the essential provisions they are substantially in accord

with ours—the items of first magnitude—but there are other items in the specification involving scientific accuracy, to which they took exception, on the basis of the scientific inaccuracy of the thing.

Vice-President Stimson:—The committees to be appointed by the American Railway Engineering Association to conduct its work for the coming year will also be approved and accepted by the Engineering Section of the newly-organized American Railroad Association. Therefore, this Committee on Yards and Terminals will be conferring with another Committee of the American Railroad Association. I believe we can safely trust them to get together on the matter—they may evolve a specification better than the one we now have.

We have a responsibility placed on us by assuming the work of the Engineering Section of the American Railroad Association, and as I see it, this is one of the first things that has come to us from that Association. The Chair thinks we are safe in giving the Committee power to act, and, of course, they will report back to the Association.

Mr. Camp:—Would there be time to submit this matter to a letter-ballot of the Association, and would decision by a letter-ballot be the proper method of handling it?

Vice-President Stimson:—If there are very important changes, that could be done; but if the changes are only in detail, it would not be necessary.

Mr. Kittredge:—We should give the United States Railroad Administration the information it has asked for. However, I should be sorry to see the high standard of our Manual lowered by any hasty or precipitate action taken by the Committee.

Mr. S. S. Roberts (U. S. R. A.):—Some of the members of this Committee take exactly the stand that has been expressed on the floor, that is, that our specifications were very carefully prepared, after joint meetings with the committees of the American Railway Association and with the manufacturers. As long as the specifications which are proposed do not differ materially from our own specifications—they differ only in minor details—we should stand pat on our own specifications, and if there are any unessential details which are advocated in the proposed specifications, which seem desirable, we probably should modify our specifications to include them.

Mr. J. R. W. Ambrose (Toronto Terminal):—I second Mr. Lindsay's motion, with the understanding that in the negotiations our Committee will have that they father their own baby, in other words, that they are to put our own specification forward as far as possible.

Mr. Reuben Hayes (Southern Railroad):—The Aishton Committee was composed in part of representatives of the Scale Manufacturers' Association, a representative of the Scale Men's Association, and a man who is, or has been, a member of the American Railway Association Committee which drafted the American Railway Association track scale specifications. He was not acting in an official capacity as representing the American Railway Association, but was appointed as an individual. There was

also represented on the Committee a railroad in the Northwest, the Minnesota Railroad and Warehouse Commission, the Bureau of Standards, and I was added to the Committee, partly through a misunderstanding—a belief that I was at that time a member of the Committee on Yards and Terminals of the American Railway Engineering Association and because of my connection, in an advisory capacity, with the Committee in the drafting of the American Railway Association specifications. Later I was added to the Committee on Yards and Terminals of this Association.

When we met to draft the Aishton specifications, we did not know which specification to follow as an outline. It was my desire to follow the American Railway Association specification, because that was the original railroad track scale specification. It was the model for the American Railway Engineering Association specification.

The representatives of the Scale Manufacturers' Association and the Minnesota Railroad and Warehouse Commission, as well as the representative of the Bureau of Standards, were of the opinion that the form of the Minnesota Railroad and Warehouse Commission's specification was superior to that of the American Railway Association specification. The rest of us saw no objection to it as to matter of form. The matter of substance is of vital importance. Therefore, we took the Minnesota specification as a model as to form.

The principal difference between the American Railway Association specification and the Aishton draft is that the American Railway Association specification uses the word "should" instead of "shall." It is entirely recommendatory. Any railroad which wishes to use that specification must rewrite it and make the word "should" read "shall," just as the other specifications of our Association use the word "shall." It does not limit the lengths and capacities to any great extent, and railroads may adopt a multitude of specifications, all in accordance with the American Railway Association specification, and when I say American Railway Association specification I mean also American Railway Engineering Association specification, because for all practical purposes they are identical; they may draft different specifications and say they are in accordance with the American Railway Association specification and the manufacturers must have an equal number of patterns, and that means an added cost in the case of every railroad that has some idea a little change here and there is necessary. The usual result is that the railroad does not secure uniform quotations, there is a compromise and the scale purchased is not in accordance with the specification which was attached to the original requisition. It is a compromise between the railroad and the manufacturer.

I do not believe that a state or a railroad can use the American Railway Association specification and get good results without remodeling it to meet the special conditions which exist. I do not mean they should remodel general principles, or that they will secure a scale that will not meet the American Railway Association specifications, but the American Railway Association specification (without revision) does not meet practical conditions.

The Aishton specification provides for two classes of scales, one for light service, that is, for service where a comparatively small number of cars will be weighed, and one for heavy service, where ordinarily a great number of cars will be weighed. Both scales are designed with the same unit stresses except for knife edges, and for the same loads. The light service scale is to be made with sectional capacities of 60 and 75 tons, and the heavy service scale with sectional capacities of 75 and 100 tons. The knife edges on the light service scale are to have a higher stress than those on the heavy service scale.

I believe that since the Railroad Administration has put up to us a question we should meet it, and answer it as quickly as circumstances will permit, and we should do so without unnecessary jealousy of any work we may have done previously, but we should stand by correct principles and the good things we have done before.

I believe that the Committee should be given such authority as may be necessary to get quick action satisfactory to both the Railroad Administration and to this Association.

Mr. J. L. Campbell (El Paso & Southwestern):—A scale specification is called for by the Railroad Administration. This Association is asked to assist in making that specification. We can trust this Committee to act for the Association representing it in the formation of the specification, depending on it to do all that it can to make that specification conform as nearly as may be to the specification of this Association.

Vice-President Stimson:—The Committee accepts the amendment made by Mr. Lindsay, that the Committee be given power to act, and the Chair would suggest adding further, "and the matter be handled under the direction of the Board of Direction."

(The motion, as stated by the Vice-President, was agreed to.)

DISCUSSION ON ELECTRICITY

(For Report, see pp. 193-205.)

(Vice-President Stimson in the Chair.)

Mr. E. B. Katte (New York Central):—Six subjects were assigned to the Committee on Electricity by the Board of Direction, the Committee is able to report on three, and asks the continuance of the other three subjects.

The first report is: "Revision of Manual." (Mr. Katte read the matter on page 104 under "Revision of Manual.")

Mr. Katte:—These definitions have been before you for a year. Some revisions have been made, they are not very important, and I move the adoption and publication in the Proceedings and in the Manual of the "Electrical Definitions," listed in the report of Sub-Committee No. 1, and that the Committee be authorized to continue the examination of subject-matter in the Manual pertaining to Electricity.

(Motion carried.)

(Mr. Katte read the matter on page 196 relating to "Clearances," and "Transmission Lines and Crossings.")

I can supplement the report by saying that delegates have been appointed, three from each of the associations; they have been working for the past month and a half, having held seven or eight meetings, and the revised specification is now in the hands of the stenographer. At the Fall meeting of the American Electric Railway Association the joint specifications will come up for approval, and it is hoped by the time of your next meeting the specifications will be in your hands for adoption, and then we will have a revised joint Overhead Transmission Line Crossing Specification, approved by all of the railroad associations.

The next subject is "Electrolysis and Insulation," Sub-Committee No. 4. The Committee has nothing to offer and there has been no meeting of the American Committee on Electrolysis during the past year. However, since the report was written there has been a meeting of the Technical Sub-Committee of the American Committee on Electrolysis. They have prepared a tentative program for the year's work, and the Chairman of the Committee, Mr. Bion J. Arnold, has been asked to call a meeting of the whole Committee, in order that this work may be started.

(Mr. Katte read the matter under "Maintenance Organization and Relation to Track Structures" and also the matter under "Water Power.")

Mr. Katte:—The Committee has to some extent investigated the utilization of water power for electric railway operation and has collected some data to indicate to what extent water power is now used to generate electricity for the operation of steam railroads.

(Mr. Katte then read from page 198 matter beginning "Norfolk & Western Railroad," and at its concluson said:)

The Committee offers this to show that water power is not always cheaper than coal.

(Mr. Katte read the matter on page 200, beginning at (b) and at its conclusion said:)

The figures in this case show that the cost of water power was but slightly less than steam. To illustrate the savings which may be expected from electric operation the Committee has cited two cases.

(Mr. Katte read near top of page 201, "A concrete example of fuel saving," etc., and after "water power" at the end of the paragraph, and said:)

That is, if the present electrified roads had been operated by electricity derived from water power, there would have been a saving of some two million tons of coal.

(Mr. Katte then read the matter beginning, "A concrete example of fuel saving near the bottom of page 201," and at its conclusion said:)

This shows the difference in saving of coal; first, if the electricity had been produced by water power, and, second, if the coal had been burned under large power plant boilers to generate electricity, as compared with burning coal in the locomotives themselves.

Attention is called to two articles pertaining to the use of water power, also to the restriction put upon water power rights by the Federal and State Governments. The conclusions of the Committee on this subject are as follows:

"(1) It is important to reduce the use of coal where possible by the development of water power.

"(2) Water power will show the greatest economy in the West on account of the higher cost of coal and minimum cost of water power development, but may show economy in other districts at present or future coal prices.

"(3) In general, auxiliary steam plants should be built to develop the water power beyond its minimum capacity, and to secure reliability of service.

"(4) Laws should be modified to permit the development of water power on public lands and on navigable streams, under reasonable restrictions.

"(5) In their studies and investigations of this subject the Committee have been impressed with the failure of some of the carriers to so keep their records as to permit the proper segregation of data which is necessary to calculate the tons of coal consumed in steam locomotives separated from coal consumed for other purposes on sections or divisions where electricity has been substituted for steam."

The Committee has found little difficulty in estimating with a fair degree of accuracy the cost of electrical operation on a given section of railroad, but it has had great difficulty in obtaining the actual cost of steam operation on the same territory.

I would move, sir, the acceptance of the report of Sub-Committee No.

(6) on Water Power, and its publication in the Proceedings as information.

(Motion carried.)

Mr. Katte:—The next subject is Item 5, "Electrical Interference," Sub-Committee (7).

(Mr. Katte read the matter on page 203.)

Mr. Katte:—I would move you, sir, the acceptance as information, and for publication in the Proceedings, of the report of Sub-Committee (7), on "Electrical Interference."

(Motion carried.)

(Mr. Katte then read the matter on page 204 headed "Proposed National Electrical Safety Code.")

Mr. Katte:—There is present this morning Mr. Wagner, of the Bureau of Standards, who has come to Chicago to discuss parts of the Code with the Committee. I would request the privilege of the floor for Mr. Wagner.

Vice President Stimson:—We will be glad to accord the privilege of the floor to Mr. Wagner.

Mr. M. H. Wagner (Electrical Engineer, Bureau of Standards):—I only came with the idea of answering questions of your Committee on Electricity, but we were not able to get together, and Mr. Katte has been very kind to give me an opportunity to tell you just what the status of the National Electrical Safety Code is to-day. I would like to have everyone here to-day familiar with the present status of it. We have a proposed revision of Part 2, which deals with the overhead and underground circuits of all kinds. We have submitted it from time to time to those who are vitally interested, for suggestions as to possible changes to be included in this revised copy and we are receiving suggestions which are of great value. This proposed revised Part 2 has been submitted to a number of conferees who are to go over it and give us the benefit of their criticism. We are about to receive these criticisms and comments, and as soon as they are in and the various suggestions have been boiled down, it is likely there will be held a conference in Washington or New York, or some other easily accessible place, where further discussion and criticism will be given. Then there will be issued a photo-lithographic copy of Part 2 of the Code, which will show clearly where changes are made. This photo-lithograph copy will be submitted to the various conferees. If there are any members of this Association who would like a copy of that report, we will gladly send it, because of our anxiety to get it before the greatest number of interested parties possible. Before closing, I want to express the Bureau of Standards' appreciation of the co-operation of your Committee on Electricity, particularly that of the Chairman, Mr. Katte, and we only hope that in the coming year we will secure the same co-operation of the Association and your Committee.

Mr. Katte:—I move the acceptance as information, and for publication in the Proceedings, of the Committee's report on the National Electrical Safety Code.

(Motion carried.)

Mr. Katte:—I move the acceptance of Recommendation No. 8, in connection with "The National Joint Committee on Overhead and Underground Line Construction," as follows: "Accept as information and publish in the Proceedings the Committee's report on the National Electrical Safety Code, and continue co-operation with the United States Bureau of Standards in the preparation of Safety Codes."

(Motion carried.)

Mr. Katte:—I move the acceptance and publication in the Proceedings of the report of the Committee as a whole.

(Motion carried.)

Vice-President Stimson:—The Committee has given us a most excellent and comprehensive report. If there is no further discussion, they are relieved with the thanks of the Association.

DISCUSSION ON TIES

(For Report, see pp. 226-238.)

(Vice-President Stimson in the Chair.)

Mr. F. R. Layng (Bessemer & Lake Erie):—The report of this Committee will be found in Bulletin 213, page 226.

The first subject which we report on is "Effect of the Design of Tie Plates and Track Spikes on the Durability of Cross-Ties."

(Mr. Layng read the matter.)

Mr. Layng:—The second subject is, "Methods in use by various railways for controlling tie renewals." I will not take the time to read the result of this work of the Sub-Committee, as it is only offered as information.

Sub-Committee No. 6 gives a report on "Trials of Substitute Ties." This is also offered as information.

I move that these three reports be received as information and published in the Proceedings.

Mr. C. E. Lindsay (U. S. R. A.):—I have not heard the Chairman make any comment on the revision of the Manual.

Vice-President Stimson:—The motion is on the acceptance as information of the Committee's report on Subjects 2, 3 and 6.

Mr. W. M. Camp (Railway Review):—Near the bottom of page 227, the Committee expresses an opinion stated in two paragraphs. I wish to ask if that is the unanimous opinion of the Committee?

Mr. Layng:—Yes, it is.

Mr. W. J. Burton (Missouri Pacific):—I think Mr. Camp has in mind the question of the desirability of screw spikes, rather than the question assigned to the Committee which was the effect of screw spikes on the durability of ties. The two questions are not exactly the same.

Mr. G. J. Ray (U. S. R. A.):—About three years ago I made a report to the Association after five or six years' experience with screw spikes in maintenance and construction work. The conclusions reached in that report stand to-day. We went into the screw spike proposition for the primary reason of saving ties. We thought we would be able to treat certain kinds of wood and establish good, long life. As Mr. Burton has said, the subject under discussion is: will the screw spike prolong the life of the tie?

One thing which I mentioned in the report just referred to, and of which I have become more convinced, is that the use of an inferior class of pine tie is not advisable on a heavy traffic road, and the screw spike does not materially lengthen the life of that tie. In other words, the tie can be so soft that even a very large flat-bottom plate and screw spikes will not materially lengthen the life.

There is another important thing which has not been given proper consideration by most of those using screw spikes, and that is the question of the standardization of the thread on the spikes. Do you realize that if you put an ordinary screw into wood and extract it immediately,

not after it has been used for years, insert another screw of the same diameter of shank with a different thread, you will spoil the threads of the wood? When you do that two or three times you can pull the screw out with your fingers. It is easy to see if you do the same thing with a screw spike, exactly the same result will follow. Some of the errors made in connection with the screw spike are due to that very cause, and some of the opinions which have been expressed in regard to the efficiency of the screw spike and on which this Committee must necessarily pass to reach conclusions, are based on that sort of information. Roads have often bought two or three different kinds of spikes, with a different kind of thread in each case, and in removing the spike from the tie and putting in another, they naturally ruin the holding power of the spike.

Regarding the conclusions on page 227, you will notice there are two main points; first, whether screw spikes will increase the durability of the ties, concerning which item there is not enough information available, and in the second conclusion the last part of the sentence reads: "And so-called permanent track where there is a more substantial foundation provided than on ordinary tie and ballast track," intimating that there is some doubt in the opinion of the Committee whether on a more or less yielding roadbed the screw spike is not a failure. It would appear that the Committee feels that on a solid concrete roadbed or permanent roadbed the screw spike may very materially increase the life of the tie, whereas they are not at all sure about it on a yielding roadbed.

In the fall of 1911 the Lackawanna Railroad put into service what was known as the Hopatcong Cutoff, 30 miles of double track, over which the main line traffic of the Lackawanna is hauled. The rail was laid on creosoted pine ties, red oak, maple, beech, gum, etc. The various classes of ties were kept separate as far as they could be, and we have had a good opportunity for a test.

The track has been in service nearly eight years. We have taken out possibly 30 or 40, or perhaps 100 ties. In all cases the ties that have been removed were perfectly sound on the outside. We had gum ties that were decayed, unquestionably before they were treated. The Committee on Wood Preservation brings out in their report presented this morning that you must be sure the tie is all right before you treat it. We had ties in which we could remove the spikes with our fingers. The tie had a good shell half-inch thick and was rotten in the center. Outside of these few cases there are no screw spikes that are loose after eight years of service, and it must be remembered that part of this line was under service in 1911 during the construction. I do not feel that we will be able to give much definite information on the effect of the screw spike on the other ties in this line for a matter of five or seven years.

When we first went into the question of creosoting ties, the problem was to get the full benefit out of the additional expense of treating. From our experience with bridge ties and all sorts of flange plates, we

came to the conclusion there was no use in putting a creosoted bridge tie on our railroad with a flanged plate. We destroyed lots of bridge ties before they were worn out, and we felt we must go to the flat-bottomed plate. We have a lot of curvature on the road and did not want to take any chances with the flat bottom plate unless we had something better than cut spikes to hold the plates in place. Thus we went to the screw spike to save the tie from mechanical wear.

If you will turn to page 135 of the report of the Committee on Wood Preservation, Bulletin 213, the Committee inserted this paragraph:

(Mr. Ray then read the paragraph beginning "A very important feature" down to "erection of the tank.")

That is exactly what we have done with reference to our track ties. We put in machines and now adze and bore the ties before they are treated, thereby preventing the destruction of the timber by cutting wood which is not properly treated.

In the same Committee's report, on page 139, in the paragraph marked A, occurs the following:

(Mr. Ray then quoted from "A careful study" down to "Mechanical wear" on page 139.)

That is exactly the problem we are up against, the question of protecting the tie, and is the reason for our using the screw spike. We believe we are getting good results.

Now in regard to screw spikes on a more or less yielding roadbed:—On this particular line above referred to we laid part of the line with 91-lb. Lackawanna rail, rolled in 1910. The rest of it was 101-lb. section rolled in 1911. We have had less rail failures on that line than on any other part of the railroad, notwithstanding the fact that we have had settlements as great as three feet on some parts of this road.

We still have a perfectly good gage condition except with a few curves where we have soft sap pine ties and where it was necessary to roll the rail. Thus the question of settlement has not had any serious effect on the holding power of the screw spikes.

The 1910 91-lb. rail has, as a rule, caused us more trouble from breakage than any other rail we ever had, but no serious trouble has developed with the rail on this line. The rail is laid on that part of the line where excessively high speeds are made by both passenger and freight trains.

Furthermore, the maintenance cost on this part of the line has been far below the average cost of maintenance on the railroad. Again, the present cost of maintenance on the entire line is the best evidence in the world that we have made no serious mistake on the screw spike proposition. During the first ten months of the year 1918, on figures given out by the United States Railroad Administration, the Lackawanna was the only railroad in the Eastern Region which had not very materially increased their maintenance expense. This may not have been due to the screw spikes in any way, but I am very sure they did not have any bad effect on the results.

Mr. F. Boardman (New York Central):—The Committee was confronted with an almost unanimous report, with two or three exceptions, from the roads of whom they asked these questions, that they did not believe in screw spikes. We had, on the other hand, the very successful installation on the Delaware, Lackawanna & Western and one or two other roads. In making these adverse criticisms in the reports, there were a number of specific reasons given; such as, "there was no form of insert so that they could renew screw plugs," and some other questions that have been brought up by Mr. Ray. They gave different reasons, and were finding different troubles, and it was the opinion of the Committee that with that information before them, it was not proper to make a general statement that screw spikes were desirable in spiking down ties unless standards of construction and maintenance were also specified. Among other things we asked for was a detailed report from the Delaware, Lackawanna & Western Railroad, which is now being gotten up to answer these specific objections.

Mr. Ray:—In what I said a minute ago I did not intend any criticism of the Committee's work. I expected just such a report. It was merely as a matter of information.

Question 5 asked by the Committee reads: "After the wood has become loose or decayed around the screw spike, have you developed any satisfactory plug to insert in the tie and thus secure a former hold? If so, please describe the plug and method of application. Under these conditions do you replace the screw spike with a cut spike?"

How are you going to plug a rotten tie? There are several schemes which have been developed that are more or less impracticable. We have tried a lot of them, and that is one of the vital questions we have to face. If for any reason a spike does get loose we have got two more holes in the tie plate in which to replace it. Our only difficulty has developed with reference to curve conditions; we have absolutely none on straight track.

Mr. Baldridge:—The Santa Fe Railroad has put in probably 100 miles of track with screw spikes, and if you ask Mr. Rex, of the Tie Department, what results we get, you will get one answer, and if you ask me, you will get another. This is a question which I think you will find has been pretty well handled by the Committee up to the present time, and from the results of the study by the Committee, there is nothing to prove that the screw spike is of any benefit in protecting the tie. In October, 1916, I inspected some track laid with screw spikes in the winter of 1910 and the spring of 1911. I used a taper gage to insert under the head of the spike to determine how much space there was between the spike and the rail, and in doing that I found probably one per cent. of the spikes were quite loose in the tie and could be readily lifted out of the tie by the fingers. Whether or not the service will eventually justify them, remains to be seen.

Mr. Camp:—Do I understand that you raised a screw spike by lifting it out with your fingers?

Mr. Baldridge:—Yes, sir; a great many of them, but you will not find that by going over the track and looking at it; you have got to bend your back and get hold of them.

Mr. Camp:—Do you know whether such looseness was due to decay of the timber or to something else?

Mr. Baldridge:—That seems to me to be due to the motion in the rail lifting the spike slightly out of place and wearing through the thread in the wood between the threads of the spike, or the wood separating the two threads.

Mr. A. S. Baldwin (Illinois Central):—What kind of timber were these ties?

Mr. Baldridge:—Most of those ties were treated. I am not sure whether all of them were or not. It was a mixture of hard pine and gum with a few oak ties, mostly treated.

Mr. H. R. Safford (U. S. R. A.):—One of the members of the Committee, I think, made the statement that the purpose in the particular language that is used at the bottom of page 227 was to correct a statement or impression now in the Manual. Do we understand that this is in effect a recommendation that something in the Manual be withdrawn or altered?

Mr. Layng:—It is not in the Manual. It is in the Proceedings for 1914 in which that statement was made. This is not recommended for the Manual.

Mr. Lindsay:—If that subject has been finished I would like to call attention to No. 3, on page 229. With the present tie situation, it seems to me that that subject is one of most vital interest. The Committee has complied with instructions, and has submitted a report on methods in use which are comprised in field inspection and post-mortem examination. Certainly the conditions of the present season will necessitate an even greater use of preliminary field inspection if railroads are to be maintained in proper condition to approach the succeeding winter. I have always advocated preliminary field inspection, coupled with an arbitrary rule that no section foreman should be allowed to put in more than a designated number of ties per rail length without asking for inspection by his superior, and I have had most excellent results from that method. The ordinary foreman will open up his track where he has a tie which he considers proper to remove, and will find that the tie alongside of it is getting soft, and while he is at it, will think he might as well take out the two ties instead of one, unless some check is placed upon his action. I would seriously urge upon the Committee the study for the succeeding report of the subject of definite methods that should be followed of preliminary inspection, rather than post-mortem examination.

(Mr. Layng's motion carried.)

Mr. Layng:—The Committee last year canvassed the Association and found that forms 301, 302, 303 and 304 were not being used by the members of the Association, and it was further stated in these replies

that there was no prospect of their using them. The Committee therefore recommends that these forms be withdrawn from the Manual. Mr. Chairman, I so move.

Mr. Lindsay:—I would like to ask if the Committee discovered from their replies received what the objection was to these forms, whether they were too voluminous, too complicated, or what was the difficulty.

Mr. Layng:—One reply that I recall suggested that it would be necessary to have a clerk on each section, in order to keep the forms up. Most of the replies simply said that they were not being used, and, further, that there was no prospect of their being used by the roads answering.

Mr. Safford:—I would certainly vote "no" on that, Mr. Chairman. I do not believe we should withdraw forms from the Manual that have been developed after some years of study by the Committee, merely because we find that they are not in general use. We have been all looking forward to the time that we could get these forms in greater use, and unless some real difficulty is suggested against them, we ought not to abandon them. The Committee apparently has not developed any material reason from these roads as to their objections, and I do not think we are doing right in arbitrarily withdrawing these forms in the absence of such objection.

Vice-President Stimson:—If that same principle was applied generally, we would not have much left in the Manual.

Mr. J. L. Campbell (El Paso & Southwestern):—I believe some better reason than that they are not used should be given before they are withdrawn without substituting something for them. If they are to be withdrawn they should be replaced by forms acceptable to the Association and that would be used.

Mr. Camp:—I would like to know what the Committee thinks of these forms, on their merits; and also is there anything back of this? Does the Committee feel that these forms are not properly drawn up?

Mr. Layng:—The Committee feels that the forms are impracticable to be kept up by section foremen. He cannot get the information that they call for, and therefore we do not feel that we should retain them in the Manual.

Mr. Camp:—Does the Committee feel that better forms could be presented for the same purpose?

Mr. Layng:—The Committee has not given that any study, and I am personally of the opinion that they could be developed and should be developed.

Mr. Lindsay:—I move you that the forms be referred to the Committee for reconsideration.

(Motion carried.)

Vice-President Stimson:—If there is no further discussion, the Committee will be relieved, with the thanks of the Association.

DISCUSSION ON STRESSES IN RAILROAD TRACK

(For Report, see pp. 215-216.)

(Vice-President Stimson in the Chair.)

Prof. A. N. Talbot (University of Illinois):—The progress report of the Committee on Stresses in Track is found on page 215, Bulletin 213.

The data of the tests referred to last year made on the Frisco Railroad have been reduced. It has been found that at a speed of fifty miles an hour (which seems to have been not an uncommon speed) the stress in the rail under the main driver of the Santa Fe type of locomotive was three and one-half to four times as great as the stress at five miles an hour.

The stress in the rail under the Pacific type of locomotive ranged from 60 to 70 per cent. more at a speed of 60 miles an hour than the stress at five miles an hour.

Tests made on the Illinois Central during the summer with the Mikado type of locomotive, showed that at 45 miles an hour, a speed materially higher than is permitted on the road, stresses were developed about twice as great as those at a speed of five miles an hour.

It is a rather significant and interesting fact that in all these cases the trailer showed an increase in stress at about the time in the revolution of the wheel which gave the highest stress under the main driver—that is, when the counterweight of the main driver was up. There was a rather marked effect of this lack of counterbalance upon the stress in the rail under the trailer. A smaller effect of the same nature was found under the truck wheels of the Illinois Central Mikado locomotive. For the Santa Fe type locomotive the maximum effect under the drivers other than the main driver was reached when the counterweights were down.

Tests were also made on ties in the track to determine from the flexure of the ties something of the bending stresses developed in the tie and of the distribution of pressure upon the ballast along the length of the tie. These results are promising, and while it is a very difficult matter to get very closely the bending moments and the distribution of pressure, it appears now that this is the best method and that we shall have some information on these points. I can only say now that the ordinary wooden cross-tie seems to be subjected to all kinds of stress, to what may be called abuse, by bending in different directions.

As is stated in the report, the Committee was disappointed last year in that the report came to the members just before the convention without giving opportunity to study the report and to make a discussion. It is hoped that the members of the Association will now discuss the subject. The Committee will particularly welcome suggestions as to what has not been done and what should be done. We realize that there are many problems which have not yet been touched upon, and I hope we may have discussion on this matter.

Mr. C. E. Lindsay (U. S. R. A.) :—I would like to ask the Committee if in their experiments they have used 8 by 8 ties? and whether they have considered the use of a 7 by 9 tie with the long axis, vertically at the joint, with a view to increasing the dimensions of the tie?

Prof. Talbot:—The Committee has used 6 by 8 ties and 7 by 9 ties with the wide dimensions horizontal, but not 8 by 8. I think it has not been developed so far that a greater vertical dimension would be of advantage. There is nothing to indicate that a decrease in the amount of bending would be of advantage to the track. It may be, however, that it is desirable, and it would be an easy thing to test.

Mr. C. P. Howard (Interstate Commerce Commission) :—I would like to ask Prof. Talbot if the increase in the static pressure developed by these experiments does not coincide closely with what was found to be the case in short spans of bridges.

Prof. Talbot:—I presume that the results would be much alike, but the conditions are considerably different. In the case of the short span bridges there is another element entering, namely, the deflection of the structure. If a bridge has a solid floor, it may be expected that the condition then aside from the deflection on the structure will be much the same as in the track.

Mr. W. M. Camp (Railway Review) :—In his introductory remarks Prof. Talbot touched upon two or three matters that seemed to me to be a very practical application of these stresses in the track. One was the fact that where the end of a tie is not well supported by a bank outside, the flexure is greater than it is where there is a good bank to support the end of the tie and the ballast.

I should think another very practical study would be the economical length of ties. I believe that in universal practice in the past that matter has been determined largely by rule of thumb. Eight feet seems to have been adopted as the standard length on the great majority of roads. Nevertheless, some roads have used 9-ft. ties and many others have used ties 8½ ft. long. There is, no doubt, an economical length of tie.

Another question which comes up in that connection is in regard to the weight of rail in relation to length of tie, and I think still other matters of this character might be found, upon investigation. It seems to me that there would be no lack of opportunity for the Committee to find practical application for these studies if they are directed along workable lines.

Prof. Talbot:—The Committee has had in mind the study of the effect of the length of tie upon the action of the track. The ties tested on the Illinois Central are 8 ft. in length, and 8 ft. 6 in. in the tests made on the Chicago, Milwaukee & St. Paul track. Perhaps other tests should be made on longer lengths of tie. These tests should be made some time after the tamping is done, because it is evident

that the conditions to which the ties are subjected immediately after tamping are far different from those prevailing after some time has elapsed.

Vice-President Stimson:—If there is no further discussion, the Committee is relieved, with the thanks of the Association for its good work.

DISCUSSION ON BUILDINGS

(For Report, see pp. 207-214.)

(Vice-President Stimson in the Chair.)

Mr. M. A. Long (Baltimore & Ohio) :—Your Committee on Buildings has held two meetings during the year and in addition to reviewing the Manual, they concentrated on two items carried over from the year before. The first work was to give definitions of terms used in the Manual and supplements thereto. These definitions are found on page 208, and they define terms that are already in the Manual or supplements. I move that these be accepted and published in the Manual.

Mr. C. E. Lindsay (U. S. R. A.) :—I understand we have adopted a rule not to discuss definitions from the floor, but I hope the editor will look over these, as one or two changes in the definitions are desirable.

Vice-President Stimson :—Members may communicate their criticism to the Committee.

(Motion carried.)

Mr. Long :—The Committee has decided to add an additional item with reference to "Coaling Stations." There has been a great deal of consideration given to the storage of coal, and a number of roads have gone to much expense for mechanical equipments for the storage of coal. The Committee considered at what point it would be economical for a railroad to go to the expense of mechanical equipment.

(Mr. Long read the paragraph headed "Coaling Stations," page 209.)

Mr. Long :—I move that this matter be published in the Manual.

Mr. R. S. Parsons (Erie) :—I think the recommendation should be modified somewhat, and made to read, "Unless said coal storage site shall be in connection with an engine coaling plant." In many instances if you use the same hopper for unloading the coal and practically the same machinery to store the coal, providing you have the space—the only additional expense is the cost of the reclaiming machinery which in some cases is simple and inexpensive. That would be used for quantities less than 75,000 tons, and could be used economically. The coal is unloaded in the hopper and by the mere shifting of a lever the flow of coal can be diverted from the coaling pockets to the storage pile and there it can be cheaply reclaimed and put directly into the hopper. We have some such plants on our line where, while the entire coaling station is an expensive one, the additional expense of permitting us to store some 30,000 tons of coal is very slight, the advantage of being able to free cars and store what coal is not put immediately into the coaling pockets and then reclaiming it from the storage pile is very great—first, by releasing cars which is a desirable thing to do, and secondly, by keeping at the coaling station an adequate supply of coal so as to save the Transportation Department the difficulty of keeping a large amount of coal in the yards to protect them in coaling the locomotives. This is especially true when the plant is located a distance

from the mines, and thirdly, the advantage of having the coal on hand for use whenever you want it.

I agree with the Committee that it is not economical to put in a storage plant for amounts less than the tonnage indicated, unless such a plant can be located immediately at the site of the coaling pockets where the coal can be handled from the separate pile into the locomotive coaling pockets without any secondary loading in cars.

Mr. Long:—The Committee considered that point, but we did not have any figures showing what the operating costs for coal would be. We were told the cost would be about 25 cents a ton, which made it look high, and we thought that we could reach the same end by recommending a ditcher or locomotive crane which could store adjacent to the coaling station; you can store a maximum of 20,000 tons, which could be reached by a locomotive crane boom and taken from the storage pile and put into the hopper of the coaling station; if you went beyond that and installed a special device the Committee felt that approximately 75,000 tons then would be about where you ought to limit the use of a locomotive crane or ditcher and begin to put in a special device for reclaiming the coal. The question is one of cost per ton handled.

Mr. Parsons:—We have four plants which have only been in operation a month or two. That is almost too short a time to determine what can be done with this apparatus. I personally feel that the reclaiming will not cost over five or six cents a ton from the storage pile.

Mr. R. H. Ford (Chicago, Rock Island & Pacific):—I assume that the Committee refers to a coaling station arranged with hoppers permitting the use of center dump cars. If the plant is so arranged that, if necessary, a temporary track can reach directly to the coal storage pile, a locomotive crane can load, switch and place the cars at a cost of approximately 10 cents a ton. The cost of twenty-five cents a ton as suggested by the Committee seems excessive and would appear to suggest a revision of local conditions.

Mr. Long:—That cost figure is brought about by the investment in a special plant for distributing coal to the storage pile and reclaiming it. That may be exaggerated. Primarily, what we had in mind was, where you had a storage pile which was less than 75,000 tons, you could not afford the cost of a special storing and reclaiming machine, which would not be used for any other work except for that particular purpose, and the chances are you would not be using it very much of the time during the day.

Mr. Ford:—Rock Island have stored coal at 29 different points over the system during the past year, placing about 300,000 tons. The cost for storage has varied from 6 to 45 cents a ton. The maximum unit costs, of course, represent forced conditions brought about by the extraordinary fuel situation and does not represent economy in coal storage, although when the figures are analyzed it does afford an opportunity for the comparison of methods for costs of storage. Our experience

the past few years shows that a propelling crane of about 25 tons is one of the most economical machines that can be used and especially if it can be coupled with cleaning the cinder pits at terminal points.

Mr. Long:—This is a very interesting subject. We felt that 75,000 tons was a fairly good point to begin to consider special type of apparatus. That is the particular point we had in mind.

(Mr. Long's motion carried.)

Mr. Long:—We recommend that the paragraph headed "Ashpits," on page 209, be added to the Manual, and in offering this would like to say that there are one or two of these in operation—how successfully, we are not prepared to state, because they have not been in service long enough. Our road has installed one which we expect to have in operation within the next week or ten days.

I move that this be adopted by the convention and published in the Manual.

Mr. H. R. Safford (U. S. R. A.):—It seems to me that it is not expedient to put this in the Manual. The Manual is recommended practice, and I understand this is a comparatively new feature, that has been tried out only to a limited extent.

Mr. Long:—That is correct.

Mr. Safford:—It seems to me, therefore, that this feature of the report ought to be received as information only.

Mr. Long:—The Committee is agreeable to that. I think it is well to have definite figures as to operating cost, or some definite statement as to its satisfactory operation before it goes in the Manual. We will consider that and offer it as information.

Vice-President Stimson:—If there is no objection, the convention will accept it as information.

Mr. Long:—We would like to add to the Manual a paragraph with reference to scales. A question came up in regard to the report that is now in the Manual, stating that it did not cover scales for handling baggage, and we offer this paragraph:

"At terminal stations, where scales can be given proper attention and where the volume of business will justify, dial scales are preferred for weighing mail, baggage and express."

Mr. Lindsay raised the question as to why we preferred the dial scale. That is simply because we can handle so much more over a dial scale than over a beam scale, so that we felt it was proper to recommend the dial scale in preference to the beam scale. That requires a whole lot of attention, but it is more efficient in the end.

Mr. Lindsay:—I take exception to the words "where scales can be given proper attention." It intimates that sometimes scales are not given proper attention, which is contrary to the principles of the Association.

Mr. Long:—That perhaps is true, but if we will stop to consider where scales are installed, and the means of access to them, we will find that

they are usually rather dark, and we are told by the sanitary experts that anything that is kept dark is not given proper attention.

(Mr. Long's motion carried.)

Mr. Long:—In Appendix B we report on design and merits of high and low platforms at passenger stations. We recommend the following two paragraphs for adoption and publication in the Manual, and the remainder of the Appendix as information and publication in the Proceedings:

"On account of the existence of high platforms at important terminal stations and the desirability of interchange of passenger equipment throughout the country, the Committee suggests that the Association recommend to the Mechanical Section of the American Railroad Association that all passenger equipment in the future be so constructed that it can be used at either high or low platforms.

"It is recommended that high platforms be provided in connection with tracks devoted exclusively to passenger business."

The Committee will withdraw the first paragraph and recommend that the last one only be published in the Manual, and that the balance of the report be published in the Proceedings as information.

(Motion as amended carried.)

Mr. Long:—We call attention to Appendix C, page 212, and recommend that the report be accepted and published in the Proceedings, and that the conclusions on page 213 be published in the Manual.

Mr. Lindsay:—It has been my experience with both of these types that the principal essential to the proper operation of either type is a downspout of ample dimensions, durable material, and provided with some means of cleaning it out and for thawing it out when it becomes frozen. With such ample downspout arrangement and with such conveniences, the butterfly type is always preferable to the umbrella type.

Mr. Long:—That is the recommendation of the Committee, and that is covered on page 212 of the report.

(Motion carried.)

Mr. Long:—In regard to the diagram on page 214, this is not submitted as a recommendation, but is presented principally to show how far present practice deviates from the recommendations of the Association. If you will review it, it will give you a good idea as to how far we are straying from the straight and narrow path, so to speak.

Vice-President Stimson:—If there is no further discussion, the Committee will be relieved, with the thanks of the Association.

DISCUSSION ON BALLAST

(For Report, see pp. 373-406.)

(Vice-President Stimson in the Chair.)

Mr. H. E. Hale (President's Conference Committee):—There is a diagram on page 377, giving an outline of a proposed ballast gang. This the Committee proposes to recommend this year to be put in the Manual. Quite a number of different diagrams for ballast gangs were considered by the Committee, and we got some very helpful suggestions from different railroads.

On the bottom of page 376 are the conclusions. It is recommended that this diagram be published in the Manual as representing good practice in the organization of the gang to raise track on new ballast under normal conditions.

I move the adoption of that diagram as a guide.

Mr. J. E. Willoughby (Atlantic Coast Line):—The diagram provides for a force of 71 men, and for a total force of 77 men. That seems to be a pretty large force. We have obtained fairly good results from a gang of 25 men. I do not know whether the Committee determined the fact that 71 men would be an economical gang to work. I have no objection to the report or to the diagram, if the Committee has ascertained that the number given is the proper number, although I do not think it would be altogether suitable for some sections of the country.

Mr. Hale:—The Committee could not obtain data giving the most economical gang, largely due to the effect of different local conditions, and the methods of accounting made the figures such that it was difficult to compare them, but the Committee felt that this size gang was, in their opinion, an economical gang, and further, they felt that it could be reduced if it was desirable to do so. That is, it could be cut in half. There are some parts of the gang which could not be cut in half, as they are composed of odd numbers of men, but the same plan could be followed in a general way with a smaller gang.

Mr. R. H. Ford (Chicago, Rock Island & Pacific):—Is it the intention of the Committee to recommend a total force of 71 men, irrespective of weight of rail, track or ballast conditions?

Mr. Hale:—We have made no difference as far as weight of rail is concerned, but we feel that local conditions would vary the conditions to some extent. The diagram is to be a guide or recommended practice. Probably local conditions will affect it materially. The Committee also felt that probably the arrangements they propose could not always be used; that is, the same gang would be changed from week to week or day to day.

Mr. Ford:—While the Committee has made considerable progress, I believe the diagram to be misleading as it stands. Perhaps this might be avoided if the title be changed to say, "A suggested diagram for a force of 77 men." This would avoid the inference that a force of 77 men is the proper force for raising track.

Mr. Hale:—The Committee will accept a change in the title—a suggested diagram is what the Committee really had in mind.

Vice-President Stimson:—The Chair would raise the point whether it is desirable to place in the Manual a chart for a gang organization such as this, or should not its adoption be deferred until it becomes a number of a series.

Mr. Hale:—That question was considered, and the thought was that there is no diagram whatever in the Manual now. The first ballast gang I had was nothing but a mob, and this diagram would have been helpful to me, to have had the ideas of the Ballast Committee as to what they thought the organization should be. Then it may be changed to suit the local conditions.

The suggestion of Chairman Stimson is in the right direction, but in the absence of any diagram in the Manual, the Committee would like to see at least one diagram put there.

Mr. C. E. Lindsay (U. S. R. A.):—The instructions to the Committee were: "Report on methods and comparative cost of applying ballast, giving special attention to the organization of the ballast gang." They have merely taken the organization and reported on that, without giving accompanying data of costs and methods. I believe one should not go into the Manual without the other.

Mr. Hale:—The Committee made an endeavor to get costs without much success. We appreciate the fact that the subject is not completed; that this is in the nature of a progress report, and we want to carry it over. The Committee felt there were two separate propositions, "organization" and "cost." While they are related, they are distinct parts of the question referred to. The Committee felt they had at least studied the subject enough to recommend one organization of a ballast gang.

(Mr. Hale's motion carried.)

Mr. Hale:—There were two other subjects assigned to the Committee, referred to on page 378, "Study and report on design of gravel washing plants" and "Study and report on design of stone crushing plants."

Your Committee thought at first they could probably design a typical plant, but as soon as we started to design a plant, we were confronted with the problem that the local conditions were so important that we were unable to design anything along that line. After we found that condition we thought possibly it would be most helpful to the Association to pick out efficient plants which were in operation and give photographs or drawings sufficient to describe their operation, and if possible the original cost and the cost of washing the gravel. Then any member of the Association would have a plant before him which was not theoretical, but an actual operating plant, which we would hope to describe clearly and which we think would be the most helpful way of handling this question. On pages 386-99 we have shown illustrations of such plants

as we were able to get this year. We hope for better results in the future.

Mr. Ford:—I hope the Board of Direction will instruct the Committee during the coming year to give more attention to the study of specifications for ballast as well as to specifications for its application. I am sure a comprehensive study in this direction is desirable. The conclusions in the Manual are of too general a character in important particulars.

Mr. Hale:—We were able to get from Mr. Cushing, of the Pennsylvania Lines West, a copy of instructions for the cleaning of ballast. The Committee thought they were interesting enough to bring to the attention of the Association.

We were also able to obtain information in connection with reinforced concrete slabs "to assist the ballast in supporting the track on soft spots." We are indebted to Mr. Bowser, of the Southern Railroad, for a copy of his paper, which is given in our report, on page 395. The Committee recommends that this be given to the Committee as one of the subjects for further consideration.

Vice-President Stimson:—If there is no further discussion, the Committee will be relieved, with the thanks of the Association.

DISCUSSION ON ROADWAY

(For Report, see pp. 159-192.)

(Vice-President Stimson in the Chair.)

Mr. W. P. Wiltsee (Norfolk & Western):—Five subjects were assigned to the Committee and we have reported on two of them. In connection with Subject 3, your Committee reported as information eight profiles of specific instances of shrinkage of embankments on the Santa Fe Railroad, giving the percentage of material required to restore the several embankments to their original width after a lapse of four years' time.

It is the intention of the Committee that these profiles be received as information.

Mr. C. P. Howard (Interstate Commerce Commission):—I would like to call attention to the fact that on these profiles there is nothing said about subsidence, and therefore we will assume that all the diminution in the size is shrinking and not subsidence. I wonder if the Committee has found out whether any of the settling was due to subsidence, and also if they made any effort to find out how the embankment was shaped toward the bottom. Frequently an embankment will have a slope of 1.5 to 1, and then toward the end of the base it may go off into a slope of 3 or 4 to 1, showing that the material has washed down.

I would like to ask the Committee whether they know how much material in excavation it took to make the banks, and whether the banks as finally shrunk were greater or less than the amount of material in excavation.

Mr. Wiltsee:—I do not think those points were considered, but the Committee will consider them this year.

Mr. R. H. Ford (Chicago, Rock Island & Pacific):—Before these profiles are received it should be noted that the amount of subsidence shown is so small as to raise a question as to their correctness in this particular.

Mr. Wiltsee:—This profile shows shrinking and not subsidence. The subject of subsidence does not enter into it.

Mr. Ford:—I will substitute "shrinkage" for "subsidence"—it applies in either case. It looks to me as if they should be carefully scrutinized before they are published in our Proceedings. The shrinkage of these banks is much less than the experience of the average man.

Mr. W. H. Hoyt (Duluth, Missabe & Northern):—It is important, in publishing a matter of this kind, that it should be carefully designated as to what it actually covers. These fills have been brought up to their original level, as I understand it, by adding more material. Now, apparently that provides not only for shrinking, but also for any subsidence that may have occurred in these fills. As this question of subsidence and shrinkage is an important one, and as these profiles do not show the class of material and many other points that might have an important bearing on the accuracy of the statements in the report, I do not think we will be justified in publishing them.

Mr. George H. Bremner (Interstate Commerce Commission) :—It is important to indicate the part of the country to which these profiles apply, so that we would better understand the conditions surrounding them.

Mr. W. M. Camp (Railway Review) :—If the members will scrutinize these profiles they will find some of the conditions under which these banks were made. I understand Mr. Ford says that the shrinkage is less than in some other cases. That may be due to the fact that the banks were well made.

Mr. Ford:—I think these diagrams as prepared are incomplete and are liable to be misconstrued. If they are to be presented they should contain sufficient information to permit them to be intelligently used, which is not the case at present.

Mr. John G. Sullivan (Canadian Pacific) :—We are discussing now a subject which was well threshed out some years ago. I am inclined to agree with Mr. Bremner that the conditions under which these profiles were prepared should be carefully stated, and that they should be supplemented in this respect before they are published. We can appreciate what will suit one case will not suit another, and for that reason the information in connection with these profiles should be given in greater detail.

Mr. Camp:—The local conditions under which the profiles were prepared are given on page 413.

Mr. Sullivan:—I would not object to it if we had 25 or 30 examples from varying parts of the country under different conditions, but to give one or two examples might be misleading.

Mr. Howard:—I think it should also be stated how the total yardage compared with the excavation. It says, "To restore the embankment to the original width." Does that mean the width at the top or the width all the way down? I would also ask whether they have taken into consideration the washed material from the bank which sometimes accumulates at the bottom. More detail should be given.

Mr. J. L. Campbell (El Paso & Southwestern) :—These profiles should be published in the Proceedings for what they are worth. Although they may not be complete, the information given by them is better than nothing.

Mr. Bremner:—These should go into the Proceedings, as Mr. Campbell has stated, and we also should have some information as to how much shrinkage was put on the original bank. It is customary for Engineers to allow 10 per cent. or 5 per cent. in the original construction. This may or may not have been done and we should have more information than is given to enable us to use the data intelligently.

Mr. Ford:—The Committee is undertaking to deal with a rather highly developed subject and they cannot be too careful in presenting data on the subject-matter which will permit of misleading conclusions.

Vice-President Stimson:—The discussion will safeguard what the

profiles cover, and will also serve as a guide for the future work of the Committee along these lines.

(The motion, that the profiles be received as information, was carried.)

Mr. Wiltsee:—On Subject 4, "prevention and cure of water pockets in roadbed," your Committee submits a report on pages 411, 416-418. The conclusions, beginning on page 416, are submitted for adoption and publication in the Manual.

Mr. Sullivan:—I think that practically everything the Committee has stated is thoroughly good practice. I would like to see them amplify, if it is possible, one feature, and that is the crowning of the roadbed. My experience has been that after we started crowning roadbeds we were getting a great deal better results in countries where material will hold water. There is some objection to it in a country where track is laid in the frost, but that is offset by the benefit you derive from the condition of the track afterwards.

One other feature that I should think might be added, although it is hard to control, and that is the time at which you lay track. If you lay track in the spring with the frost in the ground or just going, it causes more trouble in forming a pocket after the track is laid than any other one thing—the use of the grade before the track is laid by farmers, using it as a general highway. Young Engineers should do all in their power to keep the public from using roadbed in a new country before the track is laid. They might also go to extra expense in delaying their tracklaying if possible until such time as the frost is out of the ground.

Mr. Ford:—I think we all realize the force of what Mr. Sullivan has said. There is, however, one thing to which he has not alluded and which I do not see covered; that is as an investment it is very often desirable if a road can be graded a year previous to laying the rail and left to weather. Interest on the money that is expended for grading and letting it lay a year is often a good investment. Some of the paragraphs which have been alluded to here may not be necessary, but I do not take it that the Committee would make these obligatory, but are merely suggestive of a method whereby the work can be done.

Mr. Camp:—I would like to emphasize another thing, and that is the consolidating of roadbed with steam rollers or by other means. Of course, in many cases, that is not practicable, but in some it is. We have just been considering here embankments which settled out of place. The settlement might have been far less, or perhaps negligible, if those embankments could have been rolled or tramped down by teams as they were built up. Although it is a matter of some expense to build embankments in that manner it is also a matter of much expense to rebuild these embankments up to grade after shrinkage takes place.

I realize that an embankment consolidated where a tile drain is put in might not work very well. The drain might be thrown out of joint, and in that manner the drainage would be obstructed. We have

heard more about drainage in regard to track and roadbed construction, perhaps, than any other one thing. The water to be drained from under the track must come through the ballast. If the ballast becomes dirty, so that the water will not go down through, then the only opportunity for drainage is on top of the track. Unless the top of the roadbed is crowned and has a slope to the exterior, the water which settles through the ballast will be held in pockets, and when so held it will do as much damage as though there was no ditch at all. So this question of track drainage, which is so important, and about which so much has been said, depends upon the construction of the roadbed more than on any other one thing.

Mr. Sullivan:—In regard to paragraph (F), "wet cuts of clay should have sufficient crown to drain properly and the surface should be smooth. Any backfilling necessary to make a smooth surface should be made of the same material as removed, if at all porous, otherwise backfill with cinders"—it is just as important on a fill, or more important.

Mr. Wiltsee:—If we substitute the words, "all roadbed should have sufficient crown"; would that be satisfactory?

Mr. Sullivan:—I think that would be a help.

Mr. Wiltsee:—We will make that change.

Mr. Sullivan:—"And it should be maintained in this condition until ballast is placed on it."

Vice-President Stimson:—The paragraph will then read: "All roadbeds should have sufficient crown to drain properly, and the surface should be smooth, and maintained in this condition until ballast is placed." The last word in the paragraph is changed from "cut" to "roadbed."

Mr. Baldridge:—It seems to me that Article (E), on page 417, should be made to agree with Article (A), on page 418. The object is exactly the same. Article (E) does not provide for covering pipe with positively porous material, and I would suggest that both articles be made to read: "All pipe should be covered 12 inches or more with engine cinders or equally porous material, and then the trench be backfilled with the same material as removed, if at all porous," and so forth.

Mr. Wiltsee:—The Committee will accept that amendment.

Mr. C. E. Lindsay (U. S. R. A.):—There has been one feature that has not been touched upon which I think is equally important as any that have been, and that is the raising of the shoulders necessitated by the bank's subsidence or shrinkage. It is often the practice to raise those shoulders with material that is impervious to water, and the identical clay from which the embankment has been made is piled up there alongside, and prevents the escape of the water laterally. Any material deposited upon the banks for the purpose of raising the shoulders to the proper relation with the base of rail should be material that will permit of the escape of water.

Mr. Wiltsee:—Is not that covered in paragraph (G)?

Mr. Lindsay:—That is in building new roadbed. I took that to mean additional tracks.

Mr. J. L. Campbell (El Paso & Southwestern):—It would be interesting to know how many members of the Association believe they can build and maintain roadbed until the track is laid and ballasted and the desired drainage secured according to these specifications. I have no objections to these specifications. I agree to everything in them, but I have never been able to build a roadbed attaining the purpose of the specification. I have tried it on Missouri mud. However, if all who may consult this specification if it enters the Manual understand the difficulty of attaining the specified result and that failure to do so is likely, very well. I raise the question of the practicability of the specification in much of its detail.

Mr. W. H. Courtenay (Louisville & Nashville):—As I have stated to this Association before, in building a railroad it is impossible or impracticable to tell in advance what shrinkage to arrange for in the height of an embankment so as to bring the grade right when the line is in good working order. The right way to provide for that is to make allowance in width for what it is thought the shrinkage will be. A rock fill will shrink less than an earth fill. When fills are partly of earth and party of rock it is difficult to estimate the shrinkage.

There is no doubt that all these methods are theoretical. They would be admirable if they could be accomplished, but the directors who authorize the building of the railroad want to get the benefit of the expenditure as soon as possible. Track has been laid in the wintertime in order to get the quickest return on the capital invested. These conditions have to be met in some way, and the Engineer is forced to meet them in the easiest way. No corporation would stand for the gigantic expense of building enormous fills in layers and rolling every layer, which is the best way of building them. These methods are most admirable, but in the hurry-up work that is being done nowadays, methods of that kind are impracticable.

Mr. John G. Sullivan (Canadian Pacific):—I agree in general with Mr. Campbell and Mr. Courtenay, that a great many of these things are difficult to carry out, but I have had something to do with construction, and I know the great amount of work that has been done by this Committee, and I believe the Committee ought to be complimented upon getting pretty near to what we ought to do.

Mr. J. L. Campbell:—There is much in this statement which, I believe, should go into the Manual immediately, but it is so interwoven with the theoretical part that it would be difficult for the Association to attempt a separation now. Would the Committee be willing to defer inclusion in the Manual and carry the subject over for another year, studying it with special reference to the practicability of doing the things specified?

Mr. E. A. Frink (Seaboard Air Line):—Two possible causes for trouble I do not see mentioned here. One is the practice of building fills from

a trestle and dumping the earth on each side, with the result that it slopes in and forms channels and the water runs in the center. The other is the practice that I have seen of providing for possible shrinkage by piling the surplus dirt along each side of the fill on the shoulder, and it forms on each side of the track a trough that holds the water. It does not seem to me that the remedy the Committee suggests on page 418 is sufficient. It seems to me that pockets of that nature should be cured by excavating to a sufficient depth and covering it with impervious material.

About this report in general, I think it is a most excellent report. Perhaps it is ideal in some features, but it seems to me what this Association wants is the ideal. It does not mean that because we put the ideal in our Manual that we say we must live up to it, but that we want to live up to it as nearly as we can. I think that is what the Committee wants, and I think the report should go into the Manual as it stands with the single exception of paragraph (E), No. 8.

Mr. R. H. Ford (Chicago, Rock Island & Pacific):—The report is good, but a few additions and perhaps a little more matureness of thought in some of the paragraphs will make it excellent. I hope the Committee will be willing to consider it as a progress report and make a final report next year.

Vice-President Stimson:—If it is in order, the Presiding Officer would like to say something with reference to accepting this report as information. The Committee has offered it for adoption and publication in the Manual. That is the only real material recognition that a Committee gets for its work. I do not doubt but what the Committee has worked very hard on this particular subject, and if what the last speaker proposed is followed, they will feel as though their labors were in vain. Therefore, in voting, the Chair suggests that that be taken into consideration.

Mr. Ford:—This discussion so far has brought out several things which the Committee would have been unable to obtain in any other way; now, if I get the Chairman's remarks correctly, it is in effect that the discussions should be merely incidental to a practical adoption of the Committee's report thereon, because if not agreed to, the Committee in question would feel that their work was not being appreciated. This would, indeed, be unfortunate. What is wanted, I believe, is constructive discussion on reports. Their value comes, I am sure, from the presentation of the conclusions of the Committee plus the discussions when made to the point. If our Committee can review a report of progress in the light of these annual discussions, the following year the information may be ready for the Manual.

Mr. Camp:—I call attention to the fact that what goes into the Manual is not necessarily matter in final form, and I think the report of this Committee is so excellent that it should go into the Manual. This discussion has not suggested any improvement of the language of the report, except in one case, where a slight revision was made. It seems to me that the report has set a standard which we should try to live up to, and

I therefore think the fact that it might, perchance, be revised at some future time should be nothing in the way of adopting it for the Manual at the present time.

Mr. A. S. Baldwin (Illinois Central):—It is very discouraging to a Committee to submit a report of this kind, and not secure publication. I am quite sure that a number of years ago when I was doing such work, such information as is given in this report would have been very valuable. We cannot expect to have a perfect report under any conditions, and, therefore, I would like to see this report included, just as it is, in the Manual.

Mr. J. L. Campbell:—One of the reasons suggested for inclusion in the Manual is that in some respects the report is ideal. I believe it would be a mistake if this Association conceived the idea that it is an organization for the purpose of dealing in idealism. This Association is organized for the purpose of considering practical things and producing a Manual of practical recommended practice.

Mr. Frink:—There is a great deal of difference in the meaning of "ideal" and "idealism." Idealism is something probably ethereal, beyond the reach of mere man. An ideal is an entirely different thing. An ideal is something that you have before you, it is the best practice, the best thing you can get, a thing that you think should be done. That is the way I used the word "ideal" in speaking of this report. I believe this report comes pretty near being an ideal report for this subject. I do not think there is any idealism in it.

(Mr. Wiltsee's motion was put and carried.)

Vice-President Stimson:—If there is no further discussion, the Committee is relieved, with the thanks of the Association, for their very excellent work.

DISCUSSION ON RAIL

(For Report, see pp. 445-647.)

(Vice-President Stimson in the Chair.)

Mr. G. J. Ray (U. S. R. A.):—The first subject assigned the Rail Committee, "Revision of Manual," is reported on on page 446, Bulletin 214.

It is the recommendation of the Committee that the revised Specifications for Steel Rails, submitted with this report, be printed in the Proceedings for consideration and discussion during the coming year.

I want to ask the Chair to grant rail manufacturers the privilege of the floor, if they desire to discuss this matter at the present time.

In order to get it before the meeting, I move you that these revised specifications be accepted and published as information and for discussion.

Vice-President Stimson:—If there are any Rail Manufacturers present who wish to discuss this question, we will be glad to hear from them.

Mr. F. A. Weymouth:—As Secretary of the Manufacturers Rail Committee, I have been asked to present this:

"To the American Railway Engineering Association:

"The Manufacturers have had no opportunity to properly consider the requirements given in this specification. They understand, however, from Recommendation (2), page 453, of the report of the Rail Committee, that these specifications, as presented, are to be considered as a study only and not as practical specifications to be used for commercial purposes.

"It seems that in order to bring the rail specification into a practical form which can be used by railroads in contracting for their rail requirements, it will be highly desirable for the Rail Committee to have a consultation with the Rail Manufacturers."

Mr. Ray:—Permit me to say that it is the intention of the Rail Committee to ask the manufacturers to meet the Rail Committee at a meeting probably in the very near future. I do not know just when that will be, but not until after our next regular Rail Committee meeting. We want the specifications published and we want to bring them before the Association now, in order that we may have a thorough discussion, and everybody will understand the importance of what we are putting before you. If you cannot discuss the subject now because you do not know where you stand on it, do not go home and forget about it, but send the Rail Committee a written discussion. We will be glad to get that, and I assure the manufacturers that we will give them ample opportunity to shoot at this specification all they like.

Mr. C. E. Lindsay (U. S. R. A.):—I would like to ask if it would not be advisable to have an article in the specification providing for a tensile test of the lateral strength of the rail. It was disclosed last night in the lecture that there are no tests of that kind, and that the rail was weak laterally. Could there be any specification that would disclose that thing certainly?

Mr. Ray:—Mr. Lindsay, you mean to take a section of the rail head and pull it for tensile strength? What would your proposition be—to accept rail on such a test, or just for information?

Mr. Lindsay:—I thought perhaps it might develop weaknesses in the rail that might warrant its rejection.

Mr. Ray:—The difficulty is, we must be careful not to encumber our specifications on which we accept rail with any provision which makes it an impracticable proposition from the manufacturer's standpoint. From the standpoint of information, I think a good many tests, such as you suggest, have already been made for the purpose of studying a particular rail or a particular heat. I am sure that these rails which we have all been troubled with in the last nine or ten years, failing from transverse fissures, have been tested in every conceivable way. Certainly we could not put such a clause in the specifications and expect the manufacturer to hold the steel at the mill until they were turned down and tested.

Mr. E. A. Frink (Seaboard Air Line):—Mr. Chairman, on page 455, clause (C), I would suggest that this be changed to read:

"On request of the inspector, the manufacturer shall furnish one-half of the sample drilling from the ladle test ingots for check analyses."

Mr. Ray:—I think the Committee will probably be willing to accept that suggestion. It has already been mentioned since the specifications were drawn, and it will be taken into consideration.

Mr. John G. Sullivan (Canadian Pacific):—I ask if the Committee has ever studied the question of a U-rail. I have an idea if we draw the rail in the shape of a U, a pipe will not have a bad effect as in the case of a girder rail; a U-rail is well adapted to carry a vertical load, and better adapted to take the strains the rail is subjected to than an I-beam. I had authority to try out a mile or so of U-rail, but I was up against the question of getting a proper joint. I think if we could get a proper joint for the U-rail, we would get away from a great many of our troubles.

Mr. Ray:—Some of the members of the Association may know whether this question has been up in the past as a committee subject. I do not remember that it has ever been before the Association. It has been talked of, and Mr. Lindenthal gave a discussion on the subject before the New York Railroad Club some five or six years ago, and several members of the Rail Committee were there to discuss that paper. None of those discussions were in any way favorable to the proposition, as I remember them.

There are a good many reasons why it is a difficult matter to work out, but it is something that might be considered. In talking with Mr. Lindenthal after the meeting he suggested that we might make the frogs and switches out of the ordinary T-rail and use the U-rail outside.

Vice-President Stimson:—The motion is that the revised Specifications for Steel Rails submitted with the report be printed in the Proceedings for consideration and discussion during the coming year.

(Motion carried.)

Mr. Ray:—Subject 5, assigned to the Committee, is as follows: "Make critical study of joint bars from the standpoint of design and material, together with laboratory tests, including strain-gage measurements after having established a uniform method of comparative testing."

The Committee asks that the Association adopt the method of testing rail joints submitted with this report, and include it in the Manual. This will be found on page 463, Appendix B.

I will ask the Secretary to read the proposed standard test for rail joints, section by section, and if there is any criticism we will have it after he finishes the reading.

(Mr. Wickhorst read the matter on page 463.)

Mr. Ray:—In order to get this question before the house, I move you that the proposed matter be adopted by the Association and printed in the Manual.

Mr. Lindsay:—I do not know what is meant by "transverse load" under "general assembly." And I also feel that the length of rail should be specified. You would get different results if you use a full 33-ft. rail.

Mr. H. B. MacFarland (Santa Fe):—The transverse load refers to the load or application in a vertical direction. You possibly had in mind that it should be in a horizontal direction?

Mr. Lindsay:—One would gather from the word "transverse" that you set the rail either head up or head down, and apply the load transversely.

Mr. MacFarland:—I believe the Committee would be willing to make that read "Vertical Load." As to the length of the test piece, the test piece should extend over the bar six inches, and the length of it is not limited in this specification.

Mr. Baldridge:—I found in examination of failed joints that there is an idea among trackmen at least, that a good many joint failures, where the failure is in the head of the bar, are started by the wire edge on the under side of the head of the rail at the end. In the matter of testing, it might be advisable to provide for the underside of the head of the rail at the end to be rounded off slightly, before the joint is assembled for the test. I believe I am safe in saying that not more than one-half of one per cent. of the joint failures start at the bottom of the joint; almost invariably the failure begins at the top. It is a well-known law of physics that "For a body at rest to remain at rest, it must have no forces acting on it or it must have equal opposing forces acting on it." For a railway rail to remain at rest there must be an upward force equal to the load on top of the rail. That is a feature which is always ignored by the usual divinely inspired inventor of rail joints, whom most of us have run across now and then, who consider that the entire load and strain is a downward one, and I have wondered whether it would not be a matter worth while in making a test of a rail joint to support it head downward on supports spaced about as far apart as a pair of engine drivers and apply the load at two points, spaced about as the joint ties would be spaced.

That may be one of the freak forms of test which you have ruled out on the next page, but I would like to ask if that would not give some information as to why we get joint failures almost always at the top.

Mr. MacFarland:—It is not practicable, on account of there not being testing machines of various types throughout the country to take care of such a test. That would have to be a special test. The rounding off of the edges of the rails underneath to a common radius of 1/6 or ⅛ in. would not be justified in a test of this kind. The edges should be square and not rounded off, but, of course, should not have a featheredge.

Mr. Baldridge:—One reason I suggested the rounding off of the lower edge is that I think it would pay to have a man with a file to take off the featheredge on the lower side of the head of the rail at the end.

Mr. Ray:—As a matter of information, I believe the trouble Mr. Baldridge speaks of can be overcome in an easier way by making some provision in the angle bar. This has already been done, and tests are under way at the present time.

There is no question but what a lot of angle bar failures do start at the center, primarily because they are nicked by the rail. Even though the burr from the end of the rail is carefully smoothed off, the very sharp knife edge of the rail ends are just about as apt to cause trouble with the angle bar, especially if the track is not kept up in the best possible way. This condition cannot be overcome very well without rounding off the edge of the rail. Possibly provision can be better made in the angle bar if really necessary.

Mr. Baldridge:—I seriously doubt whether a depression in the angle bar is advisable at that point, as it would be weakening the angle bar at the critical point, and I think it would be much better to provide the remedy by, in some manner, rounding off the rail.

Mr. Ray:—If the gentleman will send to the Committee suggestions along that line we will consider them, but it is not a question connected with the standard test for rail joints.

Vice-President Stimson:—The motion before the convention is that the method for testing rail joints submitted with this report be adopted and included in the Manual.

(Motion carried,)

Mr. Ray:—In connection with Subject 7, I want to call the attention of the Association to the data given on page 447, headed "Special Investigations."

(Mr. Ray then read from this section of the report.)

Mr. Ray:—It is well for the Association to bear this matter in mind, and any information that can be given that will either substantiate that argument or will change the conclusions will be much appreciated.

In connection with the subject of "Rail Failure Statistics," on page 446 is given a summary which indicates that the rail failures are falling off, as we are glad to see. It is possible that the results on account of increasing the amount of tonnage from reheated blooms is having a good

effect. It may not have anything material to do with the statement given on page 446, but it is possible that it has.

The report on "Quick Bend Test for Rail" is on page 591. This describes the hydraulic bending apparatus, and gives the result of some comparisons with the drop test.

We also include Appendix I as a report on transverse fissures.

(Mr. Ray then made some quotations from Appendix I, and also outlined the data on Subjects 4, page 448, and 7 on page 451.)

Mr. Ray:—At the time the Rail report was gotten out, the report of the Sub-Committee on Subject 7, on "Intensity of Pressure Due to Wheel Loads and Resistance of Rail Steel to Crushing and Deformation," had not been received. Since that time it has been received, but the chairman of the Sub-Committee is not here and he requested Mr. Bronson to say a few words. I will ask him to tell you what has been done.

Mr. C. B. Bronson (New York Central):—Some experiments on intensity of pressure and resistance of rail steel to crushing and deformation were reported and submitted by this Committee to the convention last year. (See Report to Rail Committee No. 69.) It was a preliminary and progress report only. During the past year the work has been continued and brought to a close. The experimental work was conducted on two five-foot pieces of rail of the 100-lb. P.S. section, which was normal both in composition and physical properties. Horizontal holes were drilled across the rail head, starting at ⅛-inch from the top, and varying in steps of 1/16-inch to a depth of ⅜-inch, a total of five holes. The rails were placed in a reciprocating machine, and subjected to experimental loads from 15,000 to 30,000 lbs. in one case, and 30,000 and 35,000 lbs. in the other; the total number of passes being over 200,000 per rail. The distortion and size of the holes were determined at intervals, but the changes noted were slight, although greater when the initial load was 30,000 lbs.

At the completion of this preliminary rolling, it was decided to place these short rail lengths in regular service on the freight tracks of the Pennsylvania Railroad near Altoona station. The rails remained in service two weeks, and were then removed after having carried 427,000 tons of traffic. Decided closure of the holes occurred near the gage side, and was so great that plug gages had to be designed to obtain the measurements of the distorted and constricted holes. The rails were given another two weeks' service test at the same location under similar traffic conditions, and upon removal it was found that all holes even at a depth of ⅜-inch from the top service of the rail had entirely closed on the gage side for a distance of about ½-inch. The distortion and shape of the holes could only be determined by milling out the closed portion of each hole, until a measurable opening was secured. Successive longitudinal cuts were then taken to determine the shape of the holes as they tapered off towards the outside of the head.

A series of photomicrographs were obtained to indicate the amount

and distance in from the gage side that distortion of the grain structure had occurred. This was found to extend inward a distance of about one and one-half inches for the holes at ⅛-inch depth. It was also found that slippage had occurred in the grains in a direction transverse to the holes along the longitudinal axis, while the adjacent solid metal showed no evidence whatever of any distortion or slippage in the grain structure.

The character of the traffic over these test rails was principally heavy tonnage in 70-ton capacity cars and wheel loads on the locomotive drivers up to 35,000 lbs. The contours of the wheels passing over the rails were diversified, and consequently uniform bearing was not obtained. The contour of each rail head was badly distorted on the gage side.

Dr. P. H. Dudley also conducted a series of tests to determine the areas of contact between wheels and rail heads under actual conditions of service. Thin strips of copper sheet of 0.0015-inch thickness were used to obtain the impressions, and were placed between the wheel and rail when the wheel was jacked up, then dropped upon the copper strip, and again raised. The impression of the actual contact remained upon the copper strip and was very clear and easily measurable.

One test was made with a Pacific type locomotive whose contours were in fair condition, and 100-lb. rails, the heads of which were badly distorted on the gage side and built up, square on the outside corner. They had been in service for a ten-year period. Contacts were taken for all wheels on both sides of the locomotive, and the average intensity of pressure per square inch was found to be 82,150 lbs.

A second test was made on rails of 105-lb. section which had been in service for eight months, and a Pacific type locomotive whose wheel contours were in good condition. The average intensity of pressure in this case was only 57,425 lbs., which is 43 per cent. lower than was secured in the first test. This shows conclusively what can be secured by wheels in good condition and rail heads which have not been severely distorted.

The conclusions of the report will not be given at the present time, but simply the outline of the work which has been carried out. The findings of the Committee will be reported at a later date.

Vice-President Stimson:—In excusing this Committee with the thanks of the Association, the Chair will ask the members to send to the Committee any data they may have on this subject.

DISCUSSION ON "TRANSVERSE FISSURES"

Mr. James E. Howard (Interstate Commerce Commission):—The term "Transverse Fissure" was applied to a type of fracture which made its appearance in a rail that caused a disastrous wreck on the Lehigh Valley Railroad in the year 1911.

The fracture started in the head of the rail. It was progressive in its character, the result evidently of repeated stresses in the track, and was therefore, by definition, a fatigue fracture. The peculiarity of the fracture consisted of its having an interior origin, the nucleus of which

was located on the gage side of the head. Its interior origin was explainable by reason of the presence of cold rolling strains introduced into the head of the rail by the action of the wheel pressures. Internal strains of compression are imparted to the metal immediately below the running surface of the head, while the metal next below is put into a state of tension.

The nucleus of a transverse fissure is located in the zone of metal which the wheel pressures have put into a state of longitudinal tension. Under the influence of repeated stresses the transverse fissure extends and may separate the greater part of the head before the final fracture of the rail occurs. No common structural nor chemical reason has, up to the present time, been identified as the cause of the incipient rupture. No common metallurgical cause is necessary in fatigue fractures, since all steels are breakable.

The nucleus of the transverse fissure usually presents the silky appearance which is so much admired in specimens fractured in the testing machine, in that case indicative of a gradual separation of the metal. The extension of the fissure has smooth surfaces, with a silvery luster, a burnishing effect caused by the opposite surfaces hammering against each other as the stresses in the head are reversed under wheel loads. When the fissure has extended and reached the periphery of the head, air is admitted, and the silvery surface becomes darkened.

In regard to the magnitude of the cold rolling stresses introduced by wheel pressure; compressive stresses very commonly reach 20,000 lbs. per square inch, while those of tension range from 5,000 to 8,000 lbs. per square inch, representing permanent stresses in plus and minus directions of 25,000 to 28,000 lbs. per square inch; stresses which exceed those which engineering practice sanctions in other structural members.

Internal strains are soon acquired by the rails after they reach the track, which they retain, subject to modifications by bending stresses when wheel loads are directly upon them.

The cold rolling action of the wheels cause crosswise as well as longitudinal strains in the head of the rail, each tending toward final rupture of the steel. On account of the laminated structure in practically all rolled shapes, together with the lesser buttressing resistance of the rail head in a crosswise direction, lateral strains frequently cause incipient cracks or seams which follow the length of the rail. Shearing strains necessarily accompany those of tension and compression and play their part in promoting rupture of the steel.

This brief review enumerates some of the conditions which are present and affect steel rails, the consideration of which opens the way for a probable explanation of the behavior of the steel in the central zone of the head when subjected to the action of strong solvents.

Provided incipient cracks are formed, then treatment with an acid solvent should bring them into prominent view. If perchance the cracks thus disclosed are found to occupy a definite part of the rail, to the practical exclusion of other parts of its cross-section, it would appear

a reasonable inference that a relation exists, in the nature of cause and effect, between such cracks, which deep etching exaggerates, and the conditions which affect this particular zone of the rail head.

The lantern slides which have been presented and cuts illustrating the appearance of deeply etched surfaces of rails, which have displayed transverse fissures, are of great interest. Should they not be accepted as promising contributions which further direct attention to such conditions as may lead to the development of certain types of rail failures. prominent among which are transverse fissures.

DISCUSSION ON IRON AND STEEL STRUCTURES

(For Report, see pp. 649-694.)

(Vice-President Stimson in the Chair.)

Mr. O. E. Selby (Cleveland, Cincinnati, Chicago & St. Louis):—I will begin the reading of the material part of the report in the middle of page 650.

"The Association's General Specifications for Steel Railway Bridges were adopted in 1906, and are printed in the Manual, pp. 482 to 505, inclusive. The Specifications for Erection were adopted in 1912 and are printed in the Manual, pp. 508 to 513, inclusive.

"The revised specifications (Appendix A to this report) are submitted by your Committee as a conclusion to be printed in the Manual in place of the specifications referred to above."

I am going to move the adoption of this conclusion. The Committee and the Association are confronted with conflicting conditions, however. The Secretary tells me there is a great demand for these specifications for steel bridges. He is constantly called on to furnish copies that are used extensively throughout the country and throughout the world. It has become known, of course, that they are under revision, and naturally people who want to use the specifications will demand the latest revision. For that reason we ought to have the specifications as revised, adopted in form to promulgate. Furthermore, there is every probability that the Engineering Section of the American Railroad Association will, under the relations newly established, be calling upon this Association through this Committee for specifications for purchase for the use of the United States Railroad Administration. We ascertained yesterday, in connection with the subject of track scales, that when the Administration wants anything, it wants it quickly and wants action on it. That is another reason why we should be able to produce at the proper time a revised and up-to-date set of specifications for steel railway bridges. On the other hand, there is the unfortunate fact that the Bulletin was issued only a few days before the convention, and has not been in the hands of the members long enough for proper study and consideration. I know that a great many of the members outside of the Committee are anxious to discuss these specifications, and of course we are depending upon their suggestions. These are some of the reasons why possibly the specifications should be amended or referred back or printed as information or some other course taken, before their adoption and printing in the Manual, but in any case it is the desire of the Committee that they be discussed. We cannot improve the specifications unless we know what is the matter with them, if anything is the matter with them.

I will therefore move in behalf of the Committee the adoption of the conclusion, which includes the specifications printed beginning on page 653 and extending to page 694.

Mr. W. H. Courtenay (Louisville & Nashville):—Is there to be any discussion before the convention of these specifications? It would be a pretty heavy undertaking to go through them item by item.

Vice-President Stimson:—Discussion is invited, but I suggest that the Chairman of the Committee point out briefly the principal differences from the old specifications, and discussion be brought out in that manner.

Mr. Courtenay:—In paragraph 38 (c), the wind stresses seem to be omitted as an application of live load. It refers to the lateral force on curves, but the wind gives a lateral force on straight track. Is that intentional?

Mr. Selby:—The wind force is not omitted, it is given another name, "Lateral Force," because of the recognition of the fact that wind is only one of the forces, for which the lateral bracing of the bridge has to be designed.

Mr. Courtenay:—Admitting that, then, why do you limit it to curves? We have lateral forces on straight track.

Mr. Selby:—It is not limited to curves. The centrifugal force is defined as a lateral force on curves, but the "lateral forces" are given their proper place in paragraph 32, that is, what ordinarily has been called the "Wind Force."

Mr. F. E. Schall (Lehigh Valley):—This Bulletin 215 reached me late on March 15th, and in looking over it generally I find that the old specifications adopted by this Association have 163 paragraphs, while the new specifications submitted have 317 paragraphs.

It is impossible to form a correct idea of the effect of the great number of changes that were made in the new specifications as compared with the old ones, bearing on the sections of metal required and the design of bridges, without making a thorough investigation.

I have examined a few of the formulas changed, but, in order to be sure as to the position taken by the Committee in changing the composition of the formulas for compression members, impact requirements, etc., it will not suffice to read the specifications; it requires an analysis of the matter, to ascertain the effect the changes made will have on the general practice of designing bridges heretofore used. Do we obtain a stronger and better bridge in every respect than was obtained by the use of the specifications adopted heretofore?

I am afraid, if these specifications should go into the Manual without proper investigation and discussion, it would be regretted; it seems to me that some parts will have to be changed before they can be adopted.

I hope that if the specifications have to be issued by the Association before the regular adoption, that such copies be marked on the face of the cover as "Tentative Specifications," and that the report of the Committee be received as a progress report, giving the members an opportunity during the year to study the specifications and communicate their ideas to the Committee.

I move an amendment to the motion of the Committee to the effect that the specifications be discussed on the floor as much as can be under the circumstances, and that the rest be handled by correspondence with the Committee and the whole matter laid over until the next annual meeting; if there is urgency to have same issued, they can be marked "Tentative Specifications."

Mr. Selby:—According to the suggestion of the Chairman, I might give briefly the features in which the specifications proposed differ from the old ones. In the first place, they have been greatly amplified, as pointed out by Mr. Schall, and the number of paragraphs has been about doubled. The amplification consists largely in parts covering workmanship and details of design. Those parts are not adequately covered in the old specifications. Specifications for Erection have been added, so that the separate specifications for Fabrication and Erection, which the Association adopted at different times, have been combined into one complete set.

In the matter of loads, there has been no change in the form of the loading, but we have specified E-60 loading as the minimum.

In the matter of the basic unit stress in tension, there is no change; it remains 16,000 lbs.

In the Column formula there is a change. We have introduced a Parabolic Column formula which is not self-limiting, and which has many advantages over the straight-line formula in use in the old specifications.

The Impact formula is the one adopted by the convention a year ago. The clearance diagram is the general clearance diagram adopted by the convention two years ago.

Those are the principal features that I think of which have been changed radically. Aside from that, however, a great many details have been amplified and some have been changed.

Mr. J. J. Yates (Central Railroad of New Jersey):—Were the specifications for percentages of live load, when two, three or four tracks are simultaneously loaded, as given in paragraph 22, adopted and approved at the same time as the formula for impact in paragraph 28?

Mr. Selby:—The provision in paragraph 22 for reduction of load on multiple track bridges, in combination with the revised impact formula, gives surprisingly parallel results with the former provision for multiple track bridges in connection with the former impact formula. One of the members of the Committee has worked that out, and tells me that the results are surprisingly close.

Mr. Yates:—I have in mind comparing the old and new formulas for impact, based on a span of 100 ft. The impact by either formula is practically the same for a single-track bridge, but for a two-track bridge the impact on the center girder by the new formula would be 70 per cent., while by the old formula it would be about 60 per cent.

Mr. Selby:—It should be borne in mind that the provision for reduc-

tion of loads in paragraph 22 is not an impact formula. It has nothing to do with impact. It is based on the theory of the lack of probability of the maximum load occurring; or, I might say, the infrequency of the occurrence of the maximum load on both tracks at the same time.

Mr. Yates:—Our general experience with bridges is that the floors are light, and that the girders are about right. In this particular case, I believe you are increasing the floors and the girders in about the same ratio. If a larger reduction of load, say 10 per cent., was permitted for the center between track girder, you would increase the strength of the floor over the present specifications, but would not increase the strength of the girder to any great extent.

Mr. Selby:—There has not been any studied purpose of the Committee to increase the weight or strength of the bridges. My own impression without a detailed investigation is that the provisions of paragraph 22 will give somewhat lighter girders for multiple track bridges than the old provision.

Mr. A. Chas. Irwin (Portland Cement Association):—What I have to say will be with the idea of adding to this discussion. It is not in the nature of a minority report. The Committee has done an enormous amount of work and has made important changes in the old specifications, and considerable improvement therein. As is natural in all committee work, there has not been always, at the beginning, at least, a unanimity of opinion. Certain new provisions that have been advanced by members of the Committee have met, of course, with opposition, and it is to be assumed that complete consideration was given to everything that was proposed that had in it the elements of good practice and good theory and reason. However, you know that there is a very great tendency to hew close to what may be termed beaten tracks, and to not stray very far therefrom.

I wish to take your time for a few minutes to read an expression of thought in regard to the design of bridges that affects those fundamental things, namely, the loads that shall be used, and the stresses by which the structure shall be proportioned to carry those loads.

The specifications for steel railway bridges of the American Railway Engineering Association have had a wider and more universal use than any other specialized work produced by the Association. The old specifications as revised from time to time really marked the beginning of standard practice in the design and fabrication of railway bridges. However, many Engineers refused to accept it in its entirety, preferring to take from it and from other specifications that had been found to produce bridges that would carry their loads safely such portions as suited their fancy or individual ideas. It is noteworthy, however, that nearly all of the different specifications for railway bridges do not wander very far from well-beaten paths. A comparison of them leads one to believe that the authors of them always compared the sizes of the various members affected by the changes which he made with those produced by other

specifications and made sure that the result was practically the same. This may be said to be a high tribute to early specification writers on steel bridge design, and on first thought we might conclude that these specifications were universally good and almost perfect, since, so far as I know, there is not one single published record of a railway bridge in the United States having failed under traffic because of overload.

However, the fact that we have never had such a bridge failure is not proof that our designs have been economical and of the best. Very few railway bridges erected twenty-five or thirty years ago are now in service where they were originally constructed. Wheel loads in that time have so increased on main lines that the safe carrying capacity of parts of the structures was surpassed long before the physical condition of the bridges required their relegation to the scrap heap. Many of these bridges have been moved to branch lines or sold for use on roads where the loads were within their safe carrying capacity. This situation has brought about a very thorough investigation of the strength of what we choose to call old bridges. It was desired to retain the bridges in service at their original locations as long as practicable and we therefore began to apply to them *maximum safe unit stresses* and the heavy loading which it was desired to run over the line.

And, indeed, for what ultimate purpose was the bridge designed in the first place? We say, to carry safely the heaviest loads that would be allowed to pass over it. Truly, but what was this load? And the answer is, Cooper's E-40, 50 or 60, as the case may be. And what was the unit stress which was used in proportioning the various parts? The reply will range anywhere from 12,000 to 18,000 lbs. per sq. in. with *an "explanation"* to the effect that this low unit stress was used so as to allow for a very considerable future increase in the live load. *Then, after all, the bridge wasn't designed in the first place to fulfill the ultimate purpose of carrying safely the heaviest loads that were expected to pass over it.*

The practical result of this logical or psychological error is almost humiliating to the Engineering profession. You have had to move, scrap, or sell many bridges whose chords were amply strong to carry the augmented loads, simply because of weakness in some web members or the absence of counters or because the floor beams or stringers or connections were not equally strong with the chords. In other words, you evolved an *unbalanced design;* not one like the "one-hoss shay," but, in rural vernacular, a one "hoss" bridge for a two "hoss" purpose.

Now, there is a cure for this, but the specifications presented here for your adoption do not give it. That cure is to *design the bridge in the first place for the fulfillment of its ultimate purpose,* namely, to carry maximum load, that is, *use the maximum loading and the maximum unit stress* in proportioning the various parts of the bridge—not two-thirds of the expected load or two-thirds of the maximum unit stress, but all of them.

To illustrate how the use of a low unit stress and a less than maximum loading operates to produce an unbalanced design, consider a member in which the dead load stress is equal to the live load stress. The section of this member is determined by dividing the total stress by say 16,000. Now increase the live load 50 per cent. and the unit stress 50 per cent., giving 24,000 for the latter. The dead load has not changed, yet the load carrying capacity of that member has been increased 50 per cent. of that portion of the section designed to carry dead load. The increase in the unit stress and the live loading is the same, so that a balance is struck for the live load. Not so for the dead load. The actual load carrying capacity of the member has been increased 50 per cent. of 50 per cent cent., or 25 per cent. of its total load carrying capacity *more* than the increase in loading which it is required to carry. In other words, the unbalanced condition of the design is in direct proportion to part played by the dead load in determining the section of the member.

It is evident that with increasing span lengths in which the dead load constitutes a larger and larger percentage of the total load, this unbalanced condition is greater and greater. It is also evident that no juggling with fractions of dead and live load for members particularly influenced by dead load can ever catch up with this "will o' the wisp" of unbalanced design resulting from the influence of dead load with low design stresses. There is but that fundamental principle of design which is correct in logic, scientific in practice, unassailable as to method, namely, *the use of the maximum loading that will pass over the structure and the maximum unit stress to which the material may repeatedly be subjected with safety in the proportioning of all parts of the structure.*

Mr. Schall:—I do not mean to say that the specifications as they are submitted should be passed lightly. As far as I had an opportunity to read them over, in the short time available, there seems to be no question that we will have a better bridge, designed under the new specifications, as compared with those of 1910.

The amplifications are a necessary part of any specifications, but were left out in the old specifications—they were more general.

The Committee, however, has not pointed out the effect of the changes made in the compression formula, impact formula, etc., so that the matter might be grasped without making a detailed investigation. I am satisfied that under the new specifications we will obtain better and more lasting bridges. The question arises—What is the difference in the total weight of a given bridge designed by the new specifications as compared with those of 1910, and what is the difference in cost by following up the various details of construction called for?

I like the specifications in general, but I am not prepared to vote for their adoption at this time. If there is urgency about issuing the specifications, it can be done in the same manner as the American Society for Testing Materials does, that is, mark them "Tentative Specifications" and give the members who so desire an opportunity to use them.

Mr. Selby:—The Committee gave careful consideration to the points raised by Mr. Irwin in meetings of the Committee at which Mr. Irwin was not present. It is recognized that the low unit stress design does not give a balanced uniform margin for increase in live loads. Both the technical and psychological aspects of that method and the alternative method of designing for an enormous increase over the existing live loads were carefully considered. Prof. Turneaure is better prepared to tell why the specifications were presented in this form.

Mr. E. A. Frink (Seaboard Air Line):—This specification gives evidence of a great deal of hard work on the part of the Committee. I dislike to oppose it, but I have to. In my opinion this specification is one of the most important, possibly the most important, that this Association has to deal with. It is a long specification, and from the little inspection I have given it, it seems most admirable in design, but there is a great deal too much in this specification, as Mr. Schall well said, to pass on it within the limits of the discussion on this floor.

There are a number of things in the specification that do not seem to be right, the principal one being the loading. The Committee has proposed as a minimum live loading Cooper's E-60 loading. That is a loading, roughly speaking, of some 8,800 lbs. per ft. of track. The loading of the heaviest Mallet engine, I think, runs somewhat under that, something like 8,000 lbs., perhaps a little over. Cooper's E-50 loading runs about 7,400 lbs. in round numbers.

If we use an E-60 loading for the engines that are in use to-day, we get a structure that is not economical, because we get too much metal in the superstructure, and too little metal in proportion in the floor system for structures of fairly long span; in other words, the Cooper loading is so entirely different from the engines in use to-day that it is no longer a fair measure by which to design the strength of our bridges. The Cooper E-60 has a total of 426,000 lbs. in 48 ft., and our heaviest Mallet engines, I think, run something like 800,000 lbs. in about 100 ft. It is obvious that the one is not a fair measure of the other. It seems to me that if we adopt a standard loading, which, after all, is only a device to escape the calculations of actual wheel loads, it is time we adopt a loading which more nearly represents the actual locomotives in use.

It seems to me that the time has come when this Association should attempt, at least, to devise a standard loading. Perhaps that is more of a problem than it might seem, but still I think we ought to attempt it.

As to prescribing a minimum of Cooper's E-60 for bridges; when this specification goes into our Manual it almost has the effect of a law. It carries more weight than any other similar specification in the world could possibly carry—it certainly does in this country, and I believe it does in the world. Any company which departs from this specification materially in designing its bridges might find the after-effects decidely adverse. Therefore, we should be very cautious what loading we specify for our bridges.

For quite a number of years I have designed bridges for Cooper's E-50 loading. Sometimes the management asks me what they will carry, and I say they will carry anything that runs in the country to-day. I believe that is a fact. I would not have any hesitation in running over these bridges any locomotive that runs in this country to-day.

There are a number of roads that do not need E-60 loading or E-50 loading, and therefore I do not think we should prescribe a minimum load or any one loading as a criterion for all bridges. In fact, I am beginning to doubt whether we should put a loading in our specification at all. It seems to me it would possibly be better to put instructions in the specifications that bridges should be designed for the loading that they are to carry, with probably a reasonable margin, expressed possibly in a percentage, over that loading to allow for an increase.

We have all seen the loading on bridges increase enormously in the time within our memory. No man can say definitely that loading will not increase more, and therefore whatever we put in practice to a certain extent should be elastic, and it seems to me that instead of prescribing a definite loading we should put in a requirement that the bridges should be designed for the loading they are to carry, plus a certain margin for increase.

In paragraph 23 it is stated: "Wooden ties shall be designed for the maximum wheel load specified distributed over three ties and with 100 per cent. impact added. The fiber stress shall not exceed 2,000 lbs. per sq. in." I believe our Manual prescribes fiber stresses of 1,200 lbs. for yellow pine, and this is almost 50 per cent. in excess of that, but the loading is 100 per cent. in excess of the loading prescribed for timber trestles, and if my memory serves me rightly it is 100 per cent. in excess of the loading prescribed for wooden decks in our present steel specification. I think our present steel specification does not prescribe the impact for ties. Certainly the specification for wooden trestles does not prescribe impact.

In paragraph 24 it is stated: "Floors consisting of beams transverse to the axis of the structure shall be designed for a uniform live load of 15,000 lbs. per linear ft. for each track, when the minimum live load specified is used."

In adding the impact to that, as near as I can tell from rough figuring, it will bring it up to something like 26,000 lbs. per linear ft. of track.

I have not had time to go over these specifications carefully. There is too much matter in them, but they deserve the most careful study. To my mind that careful study can only be given by allowing the members of the Association a proper interval in which to do that, and I am in favor of the adoption of the motion which Mr. Schall made.

Mr. J. R. W. Ambrose (Toronto Terminal):—I feel that there should be no question, but, as Mr. Frink said, it is very difficult, if not impossible, to discuss intelligently an important specification like this without

having some time. It is only fair to the members that they have sufficient time to express their views, before you ask them to vote. The Engineering Institute of Canada has just completed a very fine and excellent specification under the leadership of one of your members, and I think it would be very interesting if you should ask this member, Mr. Motley, to let us know if there is any great difference between this specification which you are proposing now and the one which was proposed in the Engineering Institute of Canada.

Mr. Selby:—The Committee had the benefit of co-operation with Mr. Motley's Committee of the Canadian Institute, and one of the instructions of the Board of Direction, which we have been proceeding under, was for co-operation with the Canadian Institute as represented on this Committee by Mr. Motley. Mr. Motley was on two of the Sub-Committees which prepared these specifications. Mr. Motley can tell us to what extent the specifications drawn conform with the work of the Canadian Institute.

Mr. P. B. Motley (Canadian Pacific):—Mr. Chairman, I find myself in the rather peculiar position of a member of this Committee, and at the same time a critic of the specification as drafted. I may as well confess at once that I feel the Association will do the right thing in referring the report back for further consideration. Mr. Ambrose has asked me to state wherein the specification of the Engineering Institute of Canada differs from the one under discussion. It is impossible, in a few words, to go over all the differences, but I can say at once that apart from the question of impact it is different as regards the arrangement of the various clauses. The Institute's specification has its clauses arranged in the natural sequence followed by a designer.

The reason for having a Canadian Specification at all is that the Canadian Government is anxious to refer to a specification which has been endorsed by our National Engineering body, and while it is desirable that Canadian practice be similar to that of the United States, yet it is scarcely proper to refer to a foreign specification. The compression formula is also quite different from that in the specification before us. The Canadian specification endorses 12,000 lbs. as a base, although this is under criticism at the present time by prominent members and it may be modified before adoption. Moreover, in the specification before us certain clauses have been duplicated and small inaccuracies exist.

As far as general principles are concerned, I am inclined to agree with Mr. Irwin, who has just stated that we are not designing balanced bridges, and with Mr. Frink who has said that Cooper's system of loading scarcely corresponds with the locomotive loadings as they exist to-day. It has also been suggested that something like the wheel spacing of a "Mallet" be adopted, and in ten years from now we may have something still different before us. These undecided questions further go to show that the specification is scarcely ready for adoption.

Personally I am inclined to think that the best solution of this problem is to make two curves, one for moments and one for shears, carefully constructed to cover the maximum moments and shears caused by all existing heavy engines, such as the Santa Fe, Pacific, Mogul, Consolidation, Mallet, and any others which we are accustomed to, or likely to use. These typical engines should all have the same axle loads (say 50,000 lbs.) and the distance apart of the wheels should conform with current practice. A typical tender also could be used with characteristic axle loads and distances apart.

In order to take care of small spans, say up to 40 ft. and heavy electric locomotives, a suitable compromise curve could be made, by deflecting upwards, the curve, above described, to such a point as will represent the maximum axle load. The final curve, drawn tangent to all the plotted curves, would represent the maximum intensities found in practice.

While it may be said that a wheel load diagram is more scientific, it can also be said that no single wheel load diagram on which we can figure will ever exist, therefore, we are just as precise in using such a curve as a wheel load diagram. In addition to this the calculations are greatly simplified, therefore it cannot be said that two curves add to the work of the designer.

If these curves were based upon 50,000 lbs. per driver, they could be known as the uniform load or "U-50" curves. For higher or lower wheel loads, say 60,000 or 40,000, they would follow the direct ratio system, as used by Cooper, and be respectively "U-60" or "U-40."

I beg to submit the above suggestions for the consideration of the Committee and the Association.

Prof. A. N. Talbot (University of Illinois):—Mr. Chairman, I think that all members of the Association and Engineers generally will agree that it would be very undesirable to adopt specifications which have been in the hands of the members only two or three days. I feel that the motion made by Mr. Schall is therefore one that should be adopted, the first part of it at least. As I understand it, he put in at the end something about considering these as tentative specifications for a year. It hardly seems that we should take these as tentative specifications, for there is no standing in the Association for that term. They should either be adopted or left for consideration for a year, and I hope that the last part of the motion may be left off. It seems to me that we can well afford, in a matter of this importance, with specifications that have stood since 1913, to let this matter go over a year, and consider it, and get the benefit of the discussion of Engineers outside of the Association as well as of Engineers in the Association. It is evident that there will not be a very large amount of bridge building during the year, so that this is not an emergency matter.

Mr. Schall:—Mr. Chairman, with your permission I will withdraw the second part of the motion referred to by Prof. Talbot, with the consent of my second.

Vice-President Stimson:—That will leave the motion in effect to receive this as a progress report and leave it open for written discussion during the year, with a further report by the Committee next year.

Prof. F. E. Turneaure (University of Wisconsin):—Mr. Irwin's suggestion goes to the point of designing structures, having in mind more exactly the ultimate safe stress to which bridges may be subjected, and in proportioning the structure so that it will be what is called a balanced design, when loaded to its maximum safe load.

In the rules for the examination of old structures, adopted by the Association some years ago, an ultimate safe stress of 26,000 lbs. was suggested as the stress up to which a structure might be loaded if the detail were in satisfactory condition, and if the bridge showed no signs of over-stress. In accordance with that idea of ultimate safe stress, the Committee discussed this particular method of arriving at a design, assuming that 24,000 lbs. might be considered a safe stress with details satisfactory, and the load a perfectly static load. Should such a method be adopted, it would amount to this, that for dead load we would design for a stress of 24,000 lbs. per sq. in. (or possibly 22,000 lbs. per sq. in.), and that for the live load we would take, not the load that is now passing over the structures or the load that is anticipated in the near future, but the load that we would estimate might pass over the structures thirty or forty years hence, and then use 24,000 lbs. per sq. in. for that live load, increased by the proper amount for impact. In that way we would get a structure which would carry the anticipated load thirty years hence, say, with a stress of 24,000 lbs. per sq. in. It is perfectly plain that such a method of design would give a balanced structure. The specifications would then read something like this: For dead load, 24,000 lbs. per sq. in. unit stress; for live load 16,000 lbs. per sq. in., or for 50 per cent. increase of live load, 24,000 lbs. per sq. in.

Now the question arises, is 24,000 lbs. per sq. in. a satisfactory stress to put before the Association, before Engineers generally, and before the public, as a safe stress for all kinds of structures subjected to static load only? At the present time 16,000 lbs. per sq. in. is the working stress used in a great variety of structures and specified in many building codes; and while it is probably true that almost any experienced Bridge Engineer would be willing to use a working stress of 22,000 or 24,000 lbs. per sq. in. for a structure subjected to definite static loads and under his direct supervision, the Committee did not feel that it was desirable to set forth 24,000 lbs. per sq. in., as a safe stress for dead loads. The same line of argument was carried out in the Committee with reference not only to 24,000 lbs. per sq. in., but with reference to 18,000 and to 20,000 lbs. per sq. in. as a basic dead load stress. The result that the Committee arrived at after a good deal of discussion is indicated in the specifications. It is recognized, of course, that, as in the past, so in the future, bridges will be overloaded—loaded beyond their design load, and that use will be made of some

of the margin between the 16,000 dead load stress and the possible maximum stress of 22,000 to 24,000 lbs. In permitting such increased live load, the excess material put into the bridge for the dead load will be made use of just as it is now under careful supervision and in accordance with the best judgment of the Engineer. The difficulty involved in this general method of design is well known, and many structures have been analyzed for increased live loads that have shown the web members to be the weakest elements in the structure when it comes to permitting the passage of an extremely heavy live load. The reason is, of course, that in calculating the maximum capacity of the structure, use is made of the excess material allowed for the dead load, and this does not exist in the same proportion in the web members as it does in the chord members. This difficulty is met fairly well, in the proposed specifications, by paragraph 45, which is a little different from the old specification and provides just this: Assuming 24,000 lbs. per sq. in. as the ultimate safe stress for an overloaded structure, this rule will provide precisely 75 per cent. overload capacity for the live load. This is practically the same percentage of overload capacity that is furnished by the chord members of a 200-ft. span. A 200-ft. span designed by this method will therefore be of uniform strength throughout. In spans longer than 200 ft., the chord members have a little the best of it; in spans less than 200 ft. the web members have a little the best of it. This, in brief, is the history of this particular part of the specification.

Mr. B. R. Leffler (New York Central) :—I wish to call the attention of the members of the Association to the first line in the specification: "For fixed spans less than 300 ft. in length." It was recognized that when long spans are to be designed, higher unit stresses should be used, and such long spans also require special engineering features. I think the members should bear that in mind. I think that perhaps 90 per cent. of the bridges in this country and Canada will be covered by these specifications, which means spans of less than 300 ft.

A paragraph that has not been mentioned as tending to make a balanced structure is paragraph 27. It was recognized that in heavy ballasted floor bridges this load was of such great importance that some adjustment should be made.

"In bridges with ballasted floors, only three-fourths of the computed dead weight of the floors shall be considered."

Paragraphs 27 and 45 are two distinct advances over the old specifications in the direction of making a better structure and a balanced structure. I think the Association, in studying this specification during the year, will find stuck in, at different points, a few such little kinks which are in the direction of progress.

Mr. Irwin :—The provisions mentioned to provide a balanced design remind me somewhat of cutting off ulcers in an attempt to cure smallpox. I agree entirely with Mr. Leffler that these are steps in advance. They are in effect a recognition of the proposition that an unbalanced design results from the use of old specifications, and this condition

has met every man who has had to figure out whether or not such and such a locomotive could pass over such and such a bridge. The provisions aim to relieve him of that embarrassment that he meets when he finds that because of certain small weaknesses the large expense incurred in building the bridge in the first place must be largely thrown away, because the man who designed it did not have in mind the fulfillment of the thing that it would ultimately be supposed to do, i. e., carry with equal safety in all parts the biggest load that would ever come upon it.

These are steps in the right direction but fall far short of a solution. Bridges to which these specifications apply will have spans from very small ones up to 300 feet, giving rise to an enormous—I might say, an infinite variety of effects of the dead load on the sections of the various members of the structure. Every change of span, every difference in floor that gives the dead load a larger percentage in its influence on the total area of the various members of the structure will create a new set of conditions which no attempt at juggling with fractions of the dead load can ever meet. There is just one way to do it, that is to consider and proceed from the fundamental proposition of designing the bridge for the maximum load and maximum unit stress. I am not saying what the maximum unit stress should be, nor what the maximum load should be. Those are big subjects, but this is a big organization. It is composed of men who are experts along just exactly those lines. There is no other organization in this country or in the world that is more capable of grappling with this proposition and solving it in the best possible way. Let us do that.

(The original motion, as amended by Mr. Schall, was carried.)

Vice-President Stimson:—The report is received as a progress report

(Mr. Selby read all of page 651, and said:)

Mr. Selby:—I talked with Mr. Briggs, a member of the Bureau of Standards, yesterday, and asked him what the prospects were for a continuation of the column tests by the Bureau of Standards. Now that the war conditions have passed, Major Fischer has returned to the Bureau and taken up active work after his service in the Army. Mr. Briggs told me he was not in touch with that part of the work of the Bureau but that he felt sure some progress could be made this year on those tests. The work of making the tests is in the hands of a Sub-Committee headed by Mr. W. H. Moore, and we are only waiting for an opportunity to conclude the tests.

(Mr. Selby then read the matter under Subject 6, on page 652.)

Mr. Frink:—Why should the subject be dropped?

Mr. Selby:—For the reason that the principal materials for turntable rollers and disc bearings are steel for the rollers and phosphor bronze for the discs. The phosphor bronze specifications have been considered and adopted by the Association and the matter of steel for the rollers is included in the movable bridge specifications which have

been printed in the Proceedings and will be offered next year for adoption. The Committee feels there is nothing special about the metals for turntable rollers and disc bearings that is not covered in the other work of the Committee.

(Mr. Selby read the matter under Subject No. 7.)

Mr. Selby:—The details under this heading are expected to be presented to the convention in the report of 1920.

(Mr. Selby read the matter under Subject No. 8.)

Mr. Selby:—The Committee will ask that this subject be continued for the reason that the track scale question is a very live one and has been referred to this Association by the Railroad Administration, and this Committee would like to keep in touch with the structural features, at least, of the track scales.

I move the adoption of Section 2 of the recommendation at the bottom of page 652.

(Motion carried.)

Mr. Leffler:—I want to call attention to Subject No. 3, on movable bridge specifications. Every year we invite criticisms and discussion from our members, but they do not seem to come forth. I think the Chairman of this Committee would be glad to receive written discussions. Just a letter from the various members who are using these specifications, so that the Committee would be benefited by the criticisms. We are revising these specifications, and such criticisms would be helpful—they will not do us any good if made at the time the specifications are presented next year, so we would like to have them before that time.

One of the bridge companies has requested that we meet with their representative for a several days' conference, just to discuss these specifications. It would be better to have discussions published in the Bulletin, but it requires a great deal of labor to cover an article for the Bulletin, and if we get them in the form of a letter, it will help the Committee in its work.

Vice-President Stimson:—The Committee is excused, with the thanks of the Association for its admirable report.

DISCUSSION ON MASONRY

(For Report, see pp. 695-748.)

(Vice-President Stimson in the Chair.)

Mr. F. L. Thompson (Illinois Central):—The report of the Committee on Masonry appears in Bulletin 215, pp. 695-748.

(Mr. Thompson commented briefly on the several subjects assigned, as given on pages 695 and 696.)

Mr. Thompson:—With reference to "Concrete Culvert Pipe," dealt with in Appendix A, it is suggested this subject be reassigned for the work of the Committee next year.

Some work has been done on Subject 3, "Revision of Specifications for Plain and Reinforced Concrete," during the past year. This is a large subject and requires a great deal of time. The Committee expects to get this matter of the specifications for cleaning and reinforced concrete and for steel reinforcement submitted tentatively to the Association next year with the hope of having it ready for adoption in 1920.

On Subject No. 4, pages 702-3 give five methods of depositing concrete under water.

Report on Subject No. 5, "Disintegration of Concrete and Corrosion of Reinforcing Materials," is given in Appendix C. The Committee has gone into the matter quite thoroughly in so far as listing the different articles which have been published in connection with this matter.

Report on Subject No. 6, "Specifications for Slag Aggregate," is given in Appendix D. In checking over the different specifications for slag, it was found that about the only uniform quality of slag was the weight in lbs. per cu. ft., it being ascertained that about 70 lbs. was very nearly a uniform result. The Committee feels that where slag is used, the specification that will secure the best results will have to be worked up by the man intending to use the slag.

Subject No. 7 is reported on in Appendix E, page 748. The first division of Subject No. 7 was to report on: "The effect upon the strength and durability of concrete not having a sufficiency of moisture present throughout the period of hardening, as compared with concrete fully supplied with moisture." The Committee was very fortunate in getting the result of a series of tests made by Prof. Abrams, of Lewis Institute, Chicago.

With reference to sub-division (2) "Method of providing moisture during the period of hardening." This related to the different methods of sprinkling the concrete or putting sand or dirt on the concrete to keep it damp during the period of hardening. We have given some data on that subject in the report.

The next subject under this heading (3) "Remedy for concrete hardened with insufficient moisture." The matter relating to this subject will be found in Appendix E.

I call your attention particularly to the report on the "Effect of quantity of mixing water and curing conditions on the strength and wear

of concrete," which was a subject of a test, and the description of the same is given by Prof. Abrams.

This report goes on to show how these tests were made, the type of wrapper used, etc. I call your attention especially to page 722.

(Mr. Thompson here read the matter beginning at the last paragraph of page 722.)

Mr. Thompson:—I think a great deal of concrete work has been put in on railroads, and possibly more on building work, where the concrete is very wet, coming through long spouts, and the only way it will move through the spouts is by having it wet, and these tests go to show in mixing concrete in that way a great deal of the strength is lost. On page 725 some good points are made.

(Mr. Thompson then read the matter beginning, "To produce a workable concrete.")

Mr. Thompson:—This goes to show that by carefully watching the amount of water that goes into the mixture we can obtain a much stronger concrete with the same amount of strength, or the same strength of concrete, with less cement. When we can get good results with practically no extra cost, except supervision, why should we go to the expense of trying to obtain cement, that is, a finer cement ground to a finer degree, at extra cost? This is being advocated by the Government, that is, increasing the amount that will pass through a sieve, two per cent. I think the test described on page 725 should be carefully read by all the members who have anything to do with concrete work.

Vice-President Stimson:—This is certainly a very valuable report, and contains some excellent information.

Prof. A. N. Talbot (University of Illinois):—Recently I talked with two Engineers concerning improvements in making and placing concrete. Both agreed that changes in procedure might be made with advantage. One described a method which he favored, but said it required an artist to carry it out. The other criticized a proposed specification and said it was "only more of this artist's stuff." I have no doubt there are many who feel that much of what is proposed for the improvement of concrete is unnecessary and unpractical—mere "artist's stuff." Familiarity with mixing and placing concrete is likely to breed contempt for rules and regulations, especially when the ill effects of the disregard of proper precautions and workmanlike methods are not apparent to those doing the work. There are, of course, many places where concrete is used for filling material and to give weight, or where the stresses are extremely low, and here the quality of the concrete may not be important. Where durability and strength are essential, however, quality is important, and improvements in methods and requirements should be welcomed. Discussions on how to produce good concrete must add to our information, help to make us better workmen, and aid in securing a much better grade of concrete. It seems to me, therefore, that the valuable contribution of Professor Abrams, given as an appendix to the report of the Committee, will be appreciated by the Society. I heartily concur in the recommenda-

tion of the Chairman of the Committee that the paper is one worthy of the careful study of all members interested in concrete and I, too, wish to urge the careful consideration of a number of the matters therein discussed.

Concrete is a complex product. Many elements enter into the development of its strength. As it is well to have some idea of the physical conditions which affect concrete in its making, I have jotted down a number of items which seem to me to bear on the effect of the makeup of the mixture; these are offered as suggestive of the way in which the amount of water used in mixing and the gradation or variation of size of the particles making up the combination of fine and coarse aggregate may be expected to influence the strength of the concrete. These statements may seem elementary; in many respects they are crude. They are presented, however, with the thought that even a general conception of the physical conditions will be helpful in understanding the effect of changes in amount of mixing water and of variations in the size of the fine and coarse aggregate. It is to be understood that there are limitations and qualifications that will not be expressed here. Here are the items:

1. The cement and the mixing water may be considered together to form a paste; this paste becomes the glue which holds the particles of aggregate together.

2. The volume of the paste is approximately equal to the sum of the volume of the particles of the cement and the volume of the mixing water.

3. The strength given by this paste is dependent upon its concentration—the more dilute the paste, the lower its strength; the less dilute, the greater its strength.

4. The paste coats or covers the particles of aggregate partially or wholly and also goes to fill the voids of the aggregate partially or wholly. Full coating of the surface and complete filling of the voids are not usually obtained.

5. The coating or layer of paste over the particles forms the lubricating material which makes the mass workable; that is, makes it mobile and easily placed to fill a space compactly.

6. The requisite mobility or plasticity is obtained only when there is sufficient paste to give a thickness of film or layer of paste over the surface of the particles of aggregate and between the particles sufficient to lubricate these particles.

7. Increase in mobility may be obtained by increasing the thickness of the layer of paste; this may be accomplished either by adding water (resulting in a weaker paste) or by adding cement up to a certain point (resulting in a stronger paste).

8. Factors contributing to the strength of concrete are then the amount of cement, the amount of mixing water, the amount of voids in the combination of fine and coarse aggregate, and the area of surface of the aggregate.

9. For a given kind of aggregate the strength of the concrete is largely dependent upon the strength of the cement paste used in the mix, which forms the gluing material between the particles of aggregate.

10. For the same amount of cement and same voids in the aggregate, that aggregate (or combination of fine and coarse aggregates) will give the higher strength which has the smaller total area of surface of particles, since it will require the less amount of paste to produce the requisite mobility and this amount of paste will be secured with a smaller quantity of water; this paste being less dilute will therefore be stronger. The relative surface area of different aggregates or combination of aggregates may readily be obtained by means of a surface modulus that may be calculated from the screen analysis of the aggregate.

11. For the same amount of cement and the same surface of aggregate, that aggregate will give the higher strength which has the less voids, since additional pore space will require a larger quantity of paste and therefore more dilute paste.

12. Any element which carries with it a dilution of the cement paste may in general be expected to weaken the concrete—smaller amounts of cement, the use of additional mixing water to secure increased mobility in the mass, increased surface of aggregate, and increased voids in the aggregate all operate to lower the strength of the product.

13. In varying the gradation of aggregate a point will be reached, however, when the advantages in the reduction of surface of particles is offset by increased difficulty in securing a mobile mass, the voids are greatly increased, the mix is not workable, and less strength is developed in the concrete. For a given aggregate and a given amount of cement, a decrease in the amount of mixing water below that necessary to produce sufficient paste to occupy most of the voids and provide the lubricating layer will give a mix deficient in mobility and lower in strength.

A certain degree of mobility is necessary in order to place concrete in the forms in a compact and solid mass, the degree varying considerably with the nature of the work, and generally it will be found necessary to sacrifice strength to secure the requisite mobility. It is readily seen, however, that the effort should be made to produce as strong a cementing layer of paste as practicable by selecting the proper mixture of aggregate and by regulating the amount of mixing water.

More thorough mixing not only mixes the paste and better coats the particles, but it makes the mass mobile with a smaller percentage of mixing water and this less dilute paste results in higher strength. Any improvement in method of mixing which increases the mobility of the mass will permit the use of less dilute paste and thereby secure increased strength.

It may be added that for a small increase in the amount of mixing water the difference in the strength of the concrete after considerable time has elapsed appears to be relatively less than it is at the earlier ages; provided, of course, sufficient moisture is at hand to permit full chemical action to be maintained.

To take up another part of the report:

In Appendix E, on the effect upon strength and durability when there is not a sufficiency of moisture during the period of hardening, the Committee brings out the need of providing moisture during the early ages, but seems not to consider the great gain in strength attained over a long period of time if sufficient moisture is available nor to recognize the cessation of hardening and strengthening if the concrete remains dry. At the end of a month there may be little difference in strength between damp storage and ordinary dry storage; at the end of several years concrete provided with moisture for the continuation of the hardening process may have more than twice as much strength as that not having available moisture beyond the drying-out stage. Further, dry-stored concrete specimens put into moist conditions at an age of several years thereupon increase in strength rapidly, and the indications are that they will finally reach as great a strength as if they had been always under favorable moisture conditions. Concrete left in a room-dry storage had gained little or no strength beyond the age of 30 days was placed in moist storage conditions at an age of 2 years 4 months; at an age of 5 years its strength was nearly twice as great. Specimens made by the C. B. & Q. Railroad and stored in a workshop at Aurora showed no gain in strength beyond a few weeks even up to an age of 7 years. At 7 years 3 months specimens were placed in water, and after nine months (age of 8 years) the strength was found to have increased from 3,000 lbs. per sq. in. to 5,000 lbs. per sq. in. This gain in strength when moisture is provided is encouraging, because it means that structures exposed to rain or which may at times absorb moisture from the earth will go on gaining strength with age and thus be enabled to take greater load, and even that concrete in dry climates which lacks requisite strength through a deficiency of hardening water may be greatly benefited by providing the moisture over a sufficient time. It also shows that we must not expect that concrete in buildings subject to air of ordinary dryness will gain in strength beyond the period of drying out. In judging of final strength of concrete, distinction should then be made according to the hardening conditions to which the concrete is subjected through a considerable period.

It seems to me that the report of the Committee attaches too much value to sprinkling the surface of concrete. Sprinkling is helpful in retarding the drying of the surface, especially in places where the drying is not very rapid, and it may prevent excessive drying out and thus avoid defective concrete, but it can hardly be said to be a remedy for cessation of hydration by reason of a lack of water for hardening, and in a dry atmosphere sprinkling cannot be expected to provide sufficient moist-

ure to enable hardening to continue in such a way as to utilize the full value of the cement.

The maintenance of proper conditions for continuing the hardening action is of more importance than is usually recognized.

Mr. B. R. Leffler (New York Central):—The report of the Joint Committee recommends one minute and a half as the time for mixing the concrete. We tried that on a large job. The contractor protested very strongly against the time of mixing. We finally compromised by cutting the time to a minute. Under loose supervision the time of mixing is ordinarily about 15 or 20 seconds.

The time of mixing is an important feature in regard to the lubrication of the particles of the aggregate, so as to produce plasticity and ready flowing of the concrete. I think within certain limits it will be found that the desired plasticity can be attained with the least amount of water and the proper time of mixing.

The use of excess water is purely a contractors' method of placing the concrete with the least expense.

The question of the proper time of mixing is dependent on the kind of concrete mixer used, and I think that is an important subject for investigation. A one-minute mix might be all right with a certain type of mixer, probably a half-yard mixer; in other words, I think one way to obtain plasticity and the minimum amount of water is to use the right kind of mixer and the right time of mixing, and these are important questions that should be investigated.

I am afraid that the average contractor will protest vehemently against the one minute and a half time for mixing, even against one minute. I think he is the man who will say that the Engineer is trying to put through some of the "artistic stuff."

Mr. J. R. W. Ambrose (Toronto Terminal):—The idea of using surface area referred to by Prof. Talbot has been studied by the Works Department of the City of Toronto for the past two years, under the direction of one of our members, Mr. L. N. Edwards. I am sure if the chairman of the Committee will get in touch with Mr. R. R. C. Harris, Commissioner of Works at Toronto, he will get a vast amount of data on that subject.

Mr. George W. Kittredge (New York Central):—I want to say a word in commendation of the report and the discussion of Prof. Talbot. It is such a report and such a discussion that makes the Proceedings of this Association of such great value to its members and the public generally. If I had heard nothing except the report and Prof. Talbot's discussion, I should have been amply repaid for coming here.

Vice-President Stimson:—The Chair dislikes to close the discussions, but we have five more committee reports to dispose of, and the hour is getting quite late, as well as the closing business of the convention, and with the consent of the members of the Association I will relieve this Committee with the thanks of the Association for the work it has performed.

DISCUSSION ON WATER SERVICE

(For Report, see pp. 277-326.)

(Vice-President Stimson in the Chair.)

Mr. A. F. Dorley (Missouri Pacific):—There is one paragraph in the Manual which the Committee wishes to revise, namely, the section on "Foaming and Priming." The Committee feels that the explanation of the phenomenon commonly called "foaming," which causes so much trouble in locomotive boilers, is not satisfactory, and a revision is offered on page 280 under Appendix A. In addition, this section of the Manual is unsatisfactory in that it does not differentiate between what is called "foaming" and "priming." The section as written would lead one to believe that "foaming" and "priming" are synonymous terms, that they stand for the same boiler conditions, whereas they are entirely different things. The results on the locomotive are the same, water being carried up into the steam space and over into the cylinders, greatly impairing the output and efficiency of the locomotive, but priming and foaming arise from different causes, and this revision is intended to remove the ambiguity.

I move, Mr. Chairman, that this revision of the Manual under "Foaming and Priming," on page 280, be adopted.

(Motion carried.)

Mr. Dorley:—The Chairman requests that I briefly review Subjects 2, 3, 4, 5, and 6, on which progress reports are offered.

The progress report on the second subject is found in Appendix B, under the heading "Study regulations of Federal or State authorities relating to supply of drinking water on trains and premises of railroads."

Mr. Bardwell has kept in touch with the progress made in these regulations, but he reports a lack of developments during the last year. It seems that on account of the war conditions, State and Federal health authorities have done very little along these lines, but it is expected that the work will be taken up again, and the Committee suggests that it be instructed to keep in touch with the developments in these regulations during the coming year and make report to the next convention.

The report on Subject 3 will be found in Appendix C, "Design of impounding reservoirs and conditions under which they are economical."

The Committee feels that there is great need of information on the subject of reservoirs. There is much data available in the literature on the subject of rainfall and runoff and percolation and transpiration, and other factors that have to be considered in designing a reservoir, but the Committee has no knowledge of a definitely outlined method for assigning values to these various factors and an attempt is made by the Sub-Committee, of which Mr. Olson is Chairman, to work out such a method.

This report is one of progress and we hope to have the report in final shape for next year's convention.

Study of Subject 4, "Plans and specifications for typical water station layouts," is in progress.

On Subject 5 we offer a report of progress. The title of this subject is "Suitable types of meters for use in railroad water service, methods followed in testing and reading meters, and checking the consumption of city water." This is the work of the Sub-Committee, of which Mr. Knowles is Chairman. The report contains an interesting history of water measuring devices from the time of the early Romans, and their development to the accurate devices now in use for measuring water. It also contains an instructive paragraph on the accuracy that can be expected from meters of different sizes; a paragraph on a recommended method of reading water meters, quite an important matter in purchase of water from cities; and water companies' methods for testing and repairing meters, and so forth. This is offered as a report of progress, and the Committee desires to do additional work on the subject during the coming year.

Subject 6 is "Locomotive flue failures which may be due to improper water conditions and methods of treatment to correct such conditions." The Committee feels there is great need of information on this subject. Flue failures are becoming an increasingly troublesome and expensive part of locomotive maintenance. As a matter of fact, there is an epidemic of flue failures on practically all roads resulting in a greatly reduced life of flues. Some of these failures are undoubtedly due to the change from the old-style charcoal iron flue to the spelerized steel flue, now generally in use; some to the higher steam pressure carried in modern locomotives as compared with the lower pressures of smaller locomotives; but the Committee is prepared to admit that a part of this reduced life is undoubtedly due to harmful and deleterious impurities in many waters. The present epidemic is probably due to these three causes acting together. Mr. Bardwell, who has had charge of this Sub-Committee, gives us, in this report, the chemistry of these flue failures, in so far as they are produced from water conditions. I would like to read two paragraphs that give the remedies suggested.

(Mr. Dorley then read on page 317 two paragraphs relating to "The cure of boiler troubles.")

Please note that, in the last analysis, the cure calls for water purification before it is put into the boiler, rather than an attempt to treat the water with purifying compounds after it reaches the boiler.

Vice-President Stimson:—If there is no objection, the report on Subjects 2, 3, 4, 5, and 6, will be received as information—as progress reports.

Mr. Dorley:—The report on Subject No. 7, "Rules and examination questions for care of pumping stations," is found in Appendix F, on page 318. This report of the Sub-Committee, in the charge of Mr. Harvey, is the final report on this subject. It has been reported in progress for a number of years and has been published in previous

Bulletins. The Committee offers the report in its present form for insertion in the Manual.

I move that the report on "Instructions for the Care of Water Stations" be inserted in the Manual.

(Motion carried.)

Vice-President Stimson:—If there is no further discussion, the Committee will be relieved, with the thanks of the Association for their very good work.

DISCUSSION ON WOODEN BRIDGES AND TRESTLES

(For Report, see pp. 239-275.)

(Vice-President Stimson in the Chair.)

Mr. W. H. Hoyt (Duluth, Missabe & Northern:)—The report of the Sub-Committee on Revision of Manual is published on page 240. I will read a few of the essential features of it, to shorten the report, not because it is too long, but to bring out the fact that there have not yet been at this time any extensive tests made anywhere upon large-sized sticks, comparing treated timber with untreated timber. We found we had only two sets of tests and these varied considerably. The results of those tests are shown in the short table given on page 240.

The tables on pages 242, 243, and 244 give in detail the result of these two sets of tests that I have mentioned, and the Committee recommends no change at present in the present table in the Manual, due to the fact that we lack the proper experimental reports to draw any definite and proper conclusion.

The subject of Docks and Wharves was not considered this year, but held over for future work.

Subjects 3, 4 and 5 were combined under one Sub-Committee for study and report. The report of this Sub-Committee is found commencing on page 244 of the Bulletin. In studying this question, your Committee was impressed with the present lack of fulfilling apparently the requirements in the chapter on Wooden Bridges and Trestles. The Sub-Committee studying this question are of the opinion that this chapter should be revised in toto. When this shall be done it will probably be further considered by the Board of Direction, but in our opinion it should be done when the Manual is revised.

The latter part of the three questions, "Draw up in unified form a set of specifications for construction timbers and building lumber for use on railways," brought up the question as to just what was meant or how this question should be handled. There are two ways of handling this question of specifications. Your Committee attempted to draw up a general specification that might be used as a basis for drawing up any particular specification that might be needed. This was for the purpose of trying to keep down in volume the size of the specifications as published in the Manual. In other words, we tried to standardize the specifications. In doing this we have considered all the present specifications of these materials published for a number of years, specifications of the American Society for Testing Materials, the results of the United States Forestry Bureau's experiments, experimental results from different educational institutions, and previous specifications published in the Manual and in the Proceedings, and we gave particular attention to the specifications of all the different manufacturers. The thing that we wanted to do was not to draw details that would be hard to manufacture, or would be subject to and require special arrangements, and consequently higher cost. Therefore, we consulted very carefully the specifications of all the manu-

facturers' associations—the Southern Pine, the Western Fir Association, the Northern White Pine Association, and the Cedar Association—and tried to embody in this general specification a basis from which we could draw any particular specification required. One can very easily see that if we attempted to draw up a special specification for every kind of timber and lumber being used, a specification complete in itself, it would make a much larger book than our present Manual, or at least fully as large as that. The volumes of the American Society for Testing Materials will give you a good idea of what that means. If that is done, the specification, in our opinion, should be placed in the particular chapters on which these materials bear. If it is the intention of the Society to draw up a general specification that can be used as a basis, the Committee would be very glad to know it, and would be glad to have some discussion upon that particular point this morning. At present we submit the general specification as drawn up for information and study for this year.

Mr. Chairman, I would invite a discussion at this time upon that particular feature of this report. I appreciate that this report is similar to most of the others in that you have not yet had time to read it over, but I thought the Committee might obtain some opinions this morning from the members of the Association, as to whether or not it was desired to have a specification for all the different kinds of timber and lumber, or whether a general specification could be drawn to cover all forms of timber and lumber for railway uses.

Mr. W. H. Courtenay (Louisville & Nashville):—Mr. Chairman, there is only one comment that I will make. The Committee points out that some railways use one kind of timber, supposed to be convenient to them, and have specifications for that particular kind of timber. Other railroads may use various kinds of timber.

Mr. Hoyt:—Of course, that is true. In different parts of the country different kinds of timber are used on different railroads. If we were to attempt to draw up a detailed specification of each kind of timber, it would not only be bulky, but would only cover particular locations. It was that point of view that the Committee had in mind in trying to concentrate and draw a general specification that might be used as a basis from which detailed specifications could be drawn to cover particular locations and particular roads. The Committee simply submits this report for this year as a progress report and study, and hopes to continue it next year.

The Sub-Committee dealing with Subject No. 6 makes no report this year. It is giving at the present time study to the specification for timber of this kind, working with the Committee on Preservation, and will probably have a further report to submit next year.

Vice-President Stimson:—If there is no objection, the report will be received as a progress report and information. If there is no further discussion, the Committee will be relieved with the thanks of the Association.

DISCUSSION ON UNIFORM GENERAL CONTRACT FORMS

(For Report, see pp. 217-225.)

(Vice-President H. R. Safford in the Chair.)

Mr. E. H. Lee (Chicago & Western Indiana):—The Agreement form which the Committee offers to the Association is shown in Appendix A, page 219, and we wish to add two additional sections to that agreement.

As indicated in the portion of the report which has just been read, your Committee feels that under all the conditions, taking the country over, a really uniform contract form is difficult to formulate, one which will adequately meet all the conditions in the various sections of the country. The Committee feels that some of the provisions, at least, must be largely suggestive, and with that in mind, these two additional paragraphs which we wish to offer, are to be incorporated in the Agreement as shown in Appendix A, as Sections 9 and 10, covering two matters which should be covered in certain cases.

The Chair suggests it may be well to run through the "Agreement for Grade Crossing," which is submitted. If there is no objection, I will simply call attention to the various headings, giving any member of the Association an opportunity for suggestion or discussion, in case he has a thought to offer or an objection to make.

(Mr. Lee then read Appendix A, down to and including "Protection," on page 222.)

Mr. Lee:—At this point we wish to offer to the Association two additional paragraphs, one to cover the stock-guards and fence and another to cover the question of electrification of lines, as follows:

"Section 9. The .... Company reserves the right, so long as it maintains fence up to the point of intersection of the .... Company's track with the respective boundary lines of the .... Company's premises, to require the .... Company to build and maintain in good order, proper stock-guards at the point of intersection aforesaid, for the purpose of preventing trespass upon said Company's premises from the track or grounds of said .... Company.

"Section 10. If the .... Company shall (during the life of this contract) electrify its railroad at the said crossing, upon .... days' written notice to the .... Company, the said .... Company agrees to furnish, maintain and install such electric appliances, fixtures and appurtenances at said point of crossing as may be necessary for the safe and convenient operation of said crossing, and to the satisfaction of the Company's Engineer."

If there is no objection that will be incorporated. With those two additions, and with the further stipulation that Articles 9 to 16, inclusive, be set further back so that they shall be 11 to 18, inclusive, your Committee wishes to offer the form submitted in Appendix A, and moves that this form be adopted by this Association for incorporation in the Manual.

Mr. George W. Kittredge (New York Central):—Mr. Chairman, the day before I left home to come here I had submitted to me a contract which read the same as this one does, and I was told that if a blueprint was to

be made a part of the contract it should not appear in the whereases, but after "It is mutually agreed." There may be some legal reason why that should be so.

Vice-President Safford:—Do you offer that as a modification of this form?

Mr. Kittredge:—I give it to the Committee for what it is worth.

Mr. Lee:—The Committee would like to take this under consideration. It may be legally unsound, but in preparing this special contract form we follow the form of the Interlocking Contract which was accepted by this Association. If the criticism is sound in this case it would also hold for the Interlocking Contract.

Mr. Kittredge:—I think it would be found in hundreds of contracts.

Mr. C. E. Lindsay (U. S. R. A.):—Articles 7 and 8 on page 222 seem to cover largely the same ground, or are intermingled, particularly with the protection of the crossings and the methods of dividing the expense.

Vice-President Safford:—The motion before the house is on the adoption of the Form of Agreement for Grade Crossing, and insertion in the Manual.

(Motion carried.)

Mr. Lee:—On Subjects 3 and 4, the Committee simply wishes to report progress.

Vice-President Safford:—Any further discussion? If not, the Committee will be excused with the thanks of the Association.

DISCUSSION ON ECONOMICS OF RAILWAY OPERATION

(For Report, see pp. 431-443.)

(Vice-President Safford in the Chair.)

Vice-President Safford:—The report of the Committee on Economics of Railway Operation will be presented by Colonel F. W. Green, Chairman. Colonel Green has been "over there" and has just returned. We doubly welcome him. (Applause.)

Colonel F. W. Green (Twelfth Engineers, U. S. Army):—Mr. President and Gentlemen—I thank you for this hearty welcome. I have been out of the railway service so long that I confess utter ignorance of the operations of this Committee on "Economics of Railway Operation," and I am so certain that I cannot present the report because I know nothing about what is in it, that I am going to ask the President of the Association to indulge me to the extent of permitting the Vice-Chairman of the Committee, Mr. Hendricks, who has always done the work of this Committee, to present the report this year.

Mr. V. K. Hendricks (St. Louis-San Francisco):—Mr. Chairman, on behalf of the Committee I want to express the appreciation and pleasure we feel at the return of Colonel Green. He has been away from us a year and a half, doing a "big bit over there."

The report of the Committee is merely a report of progress on Subjects 1, 3 and 5, and on Subject 2 there is merely a brief discussion. The investigation on the collection of data on operating costs indicates that a thorough study of existing cost data would be a very expensive proposition. It would require a paid force to make it, and while the Committee recommended last year that such study should be made, it now feels that the data would be of questionable value, on account of the changes in unit prices, and that it would be better to study the methods of analyzing costs, rather than to study costs themselves, and on this subject merely reports progress. I do not believe it is worth while to read the Sub-Committee's report on that subject.

On Subject 4. "Report on the economic length of operating districts," the question has been gone into at some length, but as this question is dependent on a full consideration of all the varying features entering into it, and the application of good judgment, no definite recommendation is made.

On page 436 there are some general principles given that should be kept in mind in connection with determining the economic lengths of operating districts, these being as follows:

"(a) The number of terminals at which trains are switched and engines dispatched has a direct bearing on the cost of operation and should be a practical minimum.

"(b) It is advantageous to so locate terminals that locomotives will haul full tonnage rating over the entire operating district.

"(c) It is advantageous to locate terminals at the intersections of natural railroad routes which will develop into important gateways."

It is considered by the Committee that it is hardly worth while to place this in the Manual at this time. The Committee recommends that this report be accepted as information.

Mr. J. L. Campbell (El Paso & Southwestern) :—This is a subject on which the Association should have the benefit of the experience and co-operation of distinctly operating men. I suppose such representation on the Committee is already adequate. If not, it should be enlarged by the addition of operating men now members of the Association. If more operating men are needed in the membership they should be secured. I believe it will be recognized by this Association that this Committee is, perhaps, one of the most important of all the committees. It opens a new field of activity for the Association in which increased usefulness and effectiveness for the transportation business may be attained.

Mr. Hendricks:—In this connection, the personnel of the Committee does include a good many operating men, but unfortunately during the past year the conditions have been such that they could not devote time to this work, and I am sure that we all regret that they have not been able to do so to a greater extent.

In regard to this particular Sub-Committee No. 4, Mr. Brooke was the chairman of that Committee, and he is an operating man. It is substantially through his efforts that this Sub-Committee report was worked up. A copy was sent to all the members, including the operating men. There was some discussion of it, but not a great deal of criticism. I feel, as Mr. Campbell does, that the operating people should co-operate in getting this work into shape, as it is very important.

Colonel Green:—The speaker regrets that his military obligations were such that he has had no time to give consideration to these matters heretofore. It seems to him that just at the present time the work of this Committee is going to be especially difficult, for several reasons: First, we are in a period of flux, as we all know; labor costs and material costs are reaching unheard-of figures and it is almost impossible for anyone to estimate to-day with and degree of accuracy what these costs will be to-morrow, or a year from now, or three years from now. The international financial situation is such that a man would have to be indeed a good prophet who could prophesy with any degree of accuracy what money is going to cost in one year from now or ten years from now, or whether money will be available for these matters.

The true significance of the term "Economics of Railway Operation" is, of course, to secure that combination of facilities and the operating organization which will result in the least total expenditure of money. Both of these items will be variable and uncertain, and it seems to me for the next year or two, possibly, the work of this Committee will have to be confined to the establishment of principles, rather than the development of any definite method for ascertaining costs. That is something that has just occurred to me since I have been here. I may be wrong on it, but if anyone has given thought to the subject, I would like to hear from him.

Mr. Hendricks:—I move that the report be received as information.
(Motion carried.)

Vice-President Safford:—The Committee is relieved, with the thanks of the Association.

DISCUSSION ON ECONOMICS OF RAILWAY LOCATION

(For Report, see pp. 752-755.)

(Vice-President Safford in the Chair.)

Mr. C. P. Howard (Interstate Commerce Commission):—Five subjects were assigned to this Committee. Some of the members were in military service, and practically all were deep in War work throughout the entire period of time. Only one Sub-Committee submitted a report, Subject 3 (a), "Effect of curvature on cost of maintenance of way."

I would like to call attention to the fact that though the text of this report is brief, the conclusion indicated by the data submitted is entirely new and altogether different from the theory heretofore accepted, that curve expenses, including rail wear, generally vary directly with the degree of central angle, irrespective of the degree of curve. It has been known a long time that sharp curves were very objectionable, Wellington to the contrary notwithstanding; but this is the first time as far as known that any data has ever been submitted, tending to show that excess rail wear on curves, and perhaps some other curve expenses, vary with the square of the degree of curve.

This data and the conclusion that might be drawn from it would necessitate a radical change in the ordinary rules for the negative value of curvature, and it is hoped that discussion of the subject and especially the submission of additional data from the railroads will throw further light on the subject and enable us to reach a positive conclusion in the matter.

Mr. G. J. Ray (U. S. R. A.):—I would like to ask whether, in considering the data received, any attention was paid to the question of elevation on the curves in making comparison. That has a very vital influence in considering the matter for this reason: In the case of all freight traffic you would have very low elevation; in the case of combined freight and passenger traffic, when you have a high elevation, with freight trains moving at a slow rate of speed, the condition is about the worst possible.

Mr. Howard:—This does not give the elevation on curves. It covers two divisions of the Pennsylvania Lines, and I suppose the elevation is such as is usual. We have only been able to get data from one railroad, though we have circularized various roads.

Mr. C. E. Lindsay (U. S. R. A.):—I happen to know that these particular tracks are used for both freight and passenger and are probably elevated for about 40 miles an hour.

Mr. Howard:—It is not so much the amount of wear as the fact that it increases as the square of the degree of curve.

Mr. W. H. Courtenay (Louisville & Nashville):—Mr. Chairman, we have a new line that runs up the gorge of the upper Kentucky River, where there are a great many 10-degree curves, a very heavy per cent. of curvature. The business consists nearly altogether of coal carried out in 10,000-lb. capacity steel hoppers. The outer rail was

originally elevated for a speed of 35 miles per hour. We had so many derailments of those steel hopper cars, which I think were properly attributable partly to the condition of the track, partly to the inferior construction of cars, that we issued a strict order that trains carrying those steel hoppers should not exceed at any time 20 miles per hour. We cut down the superelevation and made the outer rail correspond to a speed of 20 miles per hour. An immediate and striking effect of that was a very rapid wear of the outer rail, and the difficulty of getting new rails delivered was so great that we restored part of the superelevation and made it a little more than that corresponding to a speed of 25 miles per hour.

I appreciate the very great value to all railroad men of getting as precise data as is possible pertaining to the wear of rails on different curves, but in the ordinary maintenance and operation of a railroad it is difficult to get data which is scientifically precise, for the simple reason that rails are sometimes renewed on a given railroad in a less state of wear than they are at other times. Our experience on coal-carrying lines with 10-degree curves is that the rail on 10-degree curves ought to be renewed at intervals of about four years. On 6-degree curves we can count on a life of eight years, and for straight track about twelve or thirteen years. While those are very rough figures, I apprehend it will be very difficult to get figures which are so nearly correct as to be useful data upon which this Association could base any general conclusion.

Mr. E. B. Katte (New York Central):—In studying rail wear, I would suggest co-operation with the Motive Power Engineers. We know that the wheel flange wear on certain types of locomotives is very much greater than on others. A great deal of thought has been given to producing a device which will tend to center the forward truck after leaving a curve, or upon entering a curve. It seems to me that if this Committee would call in some of the Motive Power Engineers, the efforts of the two interested parties might result in developing centering devices which would save both rail and wheel wear.

Mr. Courtenay:—There is one other thing that I omitted. The wear on the curves was so great that we went to oiling the flanges, and at certain curves we actually oiled the gage side of the head of the outer rail. That is a laborious undertaking, but it apparently reduced the wear. To what extent, I cannot say.

Mr. Howard:—I might say for Mr. Courtenay's information, that this report from the Pennsylvania Lines was originally made on just that subject, to determine whether or not it paid to oil rails, and this data and the study of the rail wear was obtained from that investigation. All that part about oiling the rail has been left out of this report.

As to ascertaining the time a rail has lasted in a curve, the Interstate Commerce Commission is doing that now every day. They go

over miles of railroad and look at the brand on the rail to find out how long it has been there on a curve or on a tangent. And it is not a difficult matter to determine that.

Mr. Ray:—It is difficult to tell exactly how long rail will wear on a curve. It must be remembered that you must have the same identical kind of rail on the curves that you are comparing. On our road, we have several curves that we use as test curves, and we make comparison by laying alternate rails around the curves, ten of one kind, ten of another, and ten of another. We find, for example, that ten rails of one sort will wear off about half as fast as the next ten rails, and you can readily see if you are going to make a fine calculation as to the rate of wear on different degrees of curvature, you have got to have the conditions the same. You have got to have the same kind of rails. Your comparison is not worth anything as a mathematical fact unless you have all the conditions identical. I should say it would be a very foolish conclusion to come to, that the wear on a curve varies with the square of the degree of curvature unless you have a sufficient amount of data to absolutely prove the case. It may be that it is somewhere near right. I should judge from all observations of the matter that it probably is in some such ratio, but you will always find when you go into it extensively that the wear on a curve varies in accordance with the kind of rail.

Mr. Howard:—We did not intend to offer that as a conclusion. We simply stated that the data submitted by the Pennsylvania Lines seemed to indicate it and we have asked for additional data which will either corroborate or disprove it. That is the only data we have, and that is what it seems to indicate.

Mr. J. L. Campbell (El Paso & Southwestern):—I hardly believe the case for this diagram is quite as uncertain or bad as indicated by Mr. Ray. It embodies results on two operating divisions, including a large variety of curves, rails and quality of rails, consequently it does have some value. Such observation, extended over thousands of miles of road, including all classes of rail, would add greatly to knowledge of the subject. I believe there is enough value in this diagram to justify our careful consideration.

Mr. W. M. Camp (Railway Review):—I think Mr. Katte mentioned a subject that was very important in connection with this matter, and it is a subject which seems to have been dropped in recent years. There have been many investigations made as to the characteristics of locomotive wheel base, such as the question of omitting the flange on certain of the drivers, and the manner of truck attachment to the locomotive—whether by a rigid center or by swing hangers. There have been many experiments with, or rather observations of, different wheel base arrangements on sharp curves, more especially by the mechanical department, with a view to avoid derailments. When the last investigation of this question was made by, I think, the Master Mechanics'

Association, they decided there was no advantage in omitting the flange on any of the drivers of a 10-wheel engine. I know that conclusion was rather surprising to road department officials, who had an idea that the flanging of the intermediate drivers was more or less severe on the track.

I do not know of any case where these experiments have taken the direction of determining rail wear; in other words, what has instigated these experiments in the past has been expediency, or how to keep locomotives on the track, and how to avoid spreading the rails on curves. Of course, it might be inferred that where the operation of the locomotives was severe on the gage of the rails the wear also would be severe. I know of an instance, once, where that matter was being looked into, and I was privileged to accompany the officials who made the investigations. We found steel splinters tooled from the rails, one of them 22 in. in length: I mean a steel sliver of that length that had been cut from the rail head by a wheel flange. There it was clearly shown that the wheel base arrangement of the locomotives was wearing the rail very rapidly, to the extent of actually cutting off steel, as a tool would do in a lathe.

I think that in some previous years it was proposed that the Track Committee of this Association should try to co-operate with some committee of the Master Mechanics' Association. Nothing came of it, but I think it is time, since this question of rail wear has come up, that the Board of Direction lay out a plan whereby some committee of this Association should meet a committee of the Master Mechanics' Association (which now goes by another name) and try to work out something definite in this direction; try to determine what may be the effect of flanging all the drivers of a locomotive of long wheel base; what the effect of the method of attachment of the front truck may be, not only as to the operation of the locomotive, but as to the relative resistance of operation on curves.

This question of rail wear seems to be increasing in importance. A good many think that the quality of rail steel has been deteriorating somewhat in recent years. I believe it is a very live question, and one to be taken up by this Association in co-operation with the mechanical associations.

Mr. John G. Sullivan (Canadian Pacific) :—There is one point that Mr. Katte brought out that I think would be of great advantage if we carried the idea out. I trust that he will have a little better reception than I did when I was making a study of curve resistance and I tried to find out about what percentage of ordinary freight-car wheels were removed from the cars for sharp flanges, in cases where one flange only was sharp. I got that information and it averaged about 75 per cent. of the car wheels that were removed from the freight cars had one sharp flange, and I asked a mechanical man what was the cause of that, was it mismating or was it because the truck was out of square? He said, no; neither one—it is your durned track.

In connection with that study, it would lead me to agree with Mr. Ray, I think it was, who said that the friction wear was a little less on high elevated track than when it was lower, contrary to what a good many of us, at least what I had in mind, there was not sufficient coning of the wheels to take up the difference in length say of a 12 or 14 or 16-degree curve.

I don't think that the leading wheel of a truck on the inside of a curve ever slips backward. On the contrary, the outside wheel will ride on such a large diameter that there is no slipping, only the slipping due to resistance. To illustrate that by an automobile, if you put speedometers on the rear and forward wheels of your car, you will find that you get greater mileage from your rear wheel speedometer. If we would reverse that, if we would take the case of an automobile coasting downhill, and we could have the same resistance that was required of the driving wheel, I am inclined to think that the wheel to which this resistance applied will give less mileage. I think in general that the forward wheel of a truck going around a curve will give you less mileage if it was on a speedometer than the wheel actually makes.

Mr. J. L. Campbell:—We have a standard gage branch line in the mountains surmounting an elevation of 4,000 feet in 26 miles. It is built on a 5 per cent. grade and with about as many thirty-degree curves as could be put into it. The line has been in operation twenty years. During the Winter season about two trains per week are operated. During the Summer season daily service is maintained, there being a summer resort on top of the mountain. The original rail is still in the track, some of it having been changed over on curves account of wear. When the line was put into service, the rapid wear of the rail account of curvature resulted in the invention by one of the locomotive engineers of an attachment to the locomotive whereby water was sprayed on the rail in front of the leading truck. This lubrication by water greatly reduced the rail wear. At one time use of the device was discontinued, but resumption of rapid rail wear and frequent derailment led to prompt renewal of the water lubrication.

(Mr. Howard's motion was put to vote and carried.)

Vice-President Safford:—The Committee is excused, with the thanks of the Association.

*UNIFICATION OF TERMINALS—SEATTLE DISTRICT

ADDENDA TO REPORT ON YARDS AND TERMINALS.

The unification and consolidated operation of terminals at Seattle and what is known as the Puget Sound District at the outset presented about as difficult and baffling a task as any we have had to contend with in the Northwestern Region. The terminal facilities in Seattle alone was a hard nut to crack when it came to laying out a plan of unified operation, and the Puget Sound territory was so co-related to the Seattle problem that it was necessary to take into consideration the entire territory forming and skirting the southern and eastern boundary of Puget Sound. Therefore, the territory bounded on the north by Everett, Wash., and on the south by South Tacoma was merged into what is known as the Puget Sound Terminal District, and the consolidation and unification of operation of same was studied out and effected as one large terminal. Figuratively speaking, we have in this district a three-link chain: The northern link made up of the Everett-Delta yards and terminals; the middle link made up of the Seattle-Auburn terminals, and the southern link made up of the Tacoma-South Tacoma terminals.

To best describe the unification of these terminals it would seem best to divide them into three subjects: (A) Organization; (B) Unification and Consolidation; (C) Operation.

(A) ORGANIZATION.

The entire Puget Sound Terminal District is under the jurisdiction and supervision of a Terminal Manager, located at Seattle. Each of the unified terminal yards or links (as described above) is supervised as follows:

Delta Yards, at Everett, under the Division Superintendent of the Great Northern Railroad. who reports direct to the Terminal Manager at Seattle.

The Seattle and Auburn terminals are operated under the supervision of a Terminal Superintendent, who reports directly to the Terminal Manager at Seattle.

The Tacoma and South Tacoma terminals are under the direct supervision of the Division Superintendent of the Northern Pacific Railroad. who reports directly to the Terminal Manager at Seattle, except that a small portion of the terminal yard of the Chicago, Milwaukee & St. Paul Railroad, which has not as yet been connected, is operated separately under the jurisdiction of the Division Superintendent of that road, who also reports directly to the Terminal Manager at Seattle.

Thus the entire organization for the operation of these terminals is wholly under one supervision, separate and distinct from that of the owning roads.

(B) UNIFICATIONS AND CONSOLIDATIONS.

The unifications and consolidations accomplished at each of the terminals may be briefly described as follows:

*From information furnished by R. H. Aishton, Regional Director, Northwest Region (Chicago), and L. G. Gilman, District Director (Seattle), U. S. Railroad Administration.

EVERETT, WASH. (Served by C., M. & St. P. R. R.; G. N. R. R. and N. P. R. R.)

(1) Yards. The switching and repair yards of the three railroads, which prior to unification were operated separately, have been connected up with track connections and merged into one common yard, operated under one yard office.

(2) Roundhouses. The Great Northern roundhouse is used by all lines.

(3) Freight Houses. The freight houses of the three roads named have been consolidated. All L. C. L. freight is handled through the Great Northern freight house, under one agent.

(4) Passenger Stations. The Chicago, Milwaukee & St. Paul and the Northern Pacific passenger stations have been consolidated, the Northern Pacific station being used by these two lines. The Great Northern passenger station is so located that consolidation with the other two lines was not practicable.

SEATTLE & AUBURN TERMINALS. (Served by the C., M. & St. P. R. R.; G. N. R. R.; N. P. R. R.; O.-W. R. R. & N. Co., and Pacific Coast R. R.)

(1) Yards. Prior to the government control all of these roads maintained and operated separate terminals. In the north end of the city, at Interbay, was located the Great Northern yard; in the center of the city, serving the majority of the industries, was the Northern Pacific yard; in the south end of the city were the yards of the Chicago, Milwaukee & St. Paul and the Oregon-Washington Railroad & Navigation Lines. The location of the yards and the layout of the city of Seattle did not make it practicable for the merging into one yard, but such additional track connections as were necessary were made and all of these terminal yards placed at the disposal of all the roads for their common use.

For operating purposes, later described, the Seattle terminals were divided into three districts: A, south end of the city; B, center of the city; C, north end of city. District B has a general yard office, with jurisdiction over districts A and C.

The Auburn yard of the Northern Pacific is still operated separately from their central yards, but as a part of the Seattle terminal. In connection with the Auburn yard, the Northern Pacific has a transfer shed and platform for handling L. C. L. freight, which is further described under "Operation." Car repair yards have been consolidated and all repair work is done in one yard.

(2) Roundhouses. Roundhouse for district A is used for taking care of freight and passenger engines of the C., M. & St. P. and O.-W. R. R. & N., also the switch engines serving this district. The roundhouses of the C., M. & St. P. and the N. P., which are located in district B, are used for N. P. freight and passenger engines; also switch engines serving this district. A few of the heavier engines of the C., M. & St. P. are taken care of at these roundhouses. The roundhouse of the Great Northern at Interbay is used for roundhousing freight and passenger engines of the G. N. and switch engines used in district C.

(3) Freight Houses. The volume of business in and out of Seattle made consolidation of freight houses impracticable. Therefore, the individual lines' freight houses are still in use.

(4) Passenger Stations. The passenger station facilities at Seattle have been consolidated, although no station has been abandoned. There were, and still are, two stations, but the organizations have been merged into a single one, the two stations being operated under one station superintendent.

TACOMA AND SOUTH TACOMA. (Served by the C., M. & St. P. R. R.; G. N. R. R.; N. P. R. R., and O.-W. R. R. & N. Co.)

(1) Yards. The Great Northern terminal was abandoned entirely. Track connections were made between the N. P., O.-W. R. R. & N. and a greater portion of the C., M. & St. P. yards, thus merging the entire terminal into one large switching yard, the switching being performed by the Northern Pacific. They have one joint yard office, and the entire operations are under the jurisdiction of the division superintendent of the Northern Pacific, reporting to the Terminal Manager. The small portion of the C., M. & St. P. yard not connected is operated individually by that road under its Division Superintendent, reporting to the Terminal Manager.

Repair yards of the N. P. and the O.-W. R. R. & N. have been consolidated, and repairs handled in one yard.

(2) Roundhouses. The Northern Pacific roundhouse is used by the Northern Pacific and Oregon-Washington Railroad & Navigation Lines. The Chicago, Milwaukee & St. Paul has separate roundhouse facilities.

(3) Freight Houses. The freight houses of the Northern Pacific and the Oregon-Washington Railroad & Navigation Lines have been consolidated, the Northern Pacific house being used, under the supervision of one agent. The Chicago, Milwaukee & St. Paul still maintains a separate freight house.

(4) Passenger Stations. The passenger station facilities of the Northern Pacific are now used by all lines.

(C) OPERATION.

Operations within the Puget Sound Terminal District are directly in charge of a Terminal Manager, located at Seattle. The jurisdiction of the Terminal Manager extends from the boundary of the terminal district within the zone bounded on the north by Everett, Wash., and on the south by South Tacoma, Wash. The indivdual lines operate their trains in and out of the district proper, and there is no transfer necessary at the boundary of the terminal district. The Terminal Manager is directly responsible, however, for all operations within this district. The jurisdiction of the owning road is cut off at the boundary line.

EVERETT, WASH.

The terminals at Everett and what is known as the Delta Yards are under the direct supervision of the Division Superintendent of the Great Northern, who reports directly to the Terminal Manager at Seattle. In the yards there is one yard office maintained. The roundhousing is performed by the Great Northern Railroad. One freight house is in operation, that of the Great Northern, operated by one agent, through which all L. C. L. business is handled. There is one passenger station in use by the Northern Pacific and the Oregon-Washington Railroad & Navigation Lines, the station being that of the Northern Pacific. The Great Northern operates its passenger trains in and out of its own station.

SEATTLE, WASH.

For operating purposes the yards and terminals at Seattle have been divided into three separate districts. District A, located in the south end of the city, formerly comprised the Chicago, Milwaukee & St. Paul and the Oregon-Washington Railroad & Navigation Lines' yards and ter-

minals. District B is located in the center of the city and is what formerly comprised the Northern Pacific yards and terminals. District C is located in the north end of the city, and is what was formerly the Great Northern yards and terminals.

The Seattle terminals are directly in charge of a Terminal Superintendent, who reports to the Terminal Manager. All of the districts, A, B and C, are under the direct supervision of a general yardmaster, who reports to the Terminal Superintendent. A yard office is maintained in each district, reporting to the general yard office, which is located in district B (the central district). Each of these districts has roundhouses, which are used jointly. The roundhouse in district A, on the O.-W. R. R. & N. property, is used for freight and passenger engines of the O.-W. R. R. & N. and the C., M. & St. P.; also for switch engines serving this district. There are two roundhouses in district B, the N. P. property and the C., M. & St. P. property. These are used for Northern Pacific engines and switch engines serving this territory. Some of the heavier power of the C., M. & St. P. also use these roundhouses. In district C is located the Great Northern roundhouse, at Interbay, which is used for freight and passenger engines of the Great Northern, as well as the switch engines serving this district.

The yard operations have been apportioned in accordance with their geographical location in relation to the traffic. District A is used as a receiving and break-up yard for traffic coming in from the south, transfers being made from this yard to district B—known as the middle yard. To the north, district C is used as a receiving yard and also as a break-up yard for traffic coming in from the north, and also from the east via the Great Northern. From this district cars are transferred to district B (the middle yard). The cars thus assembled in district B are distributed to the industries and docks within the city. There are a few docks of the Great Northern Railroad and the Port Commission which are located adjacent to district C. Distribution to these docks is made direct from the Interbay yard. District B (the central yard) is also used as a make-up yard for outgoing trains.

All of the individual lines' freight houses are still maintained as before, the heavy traffic making consolidations impracticable at this time. The passenger traffic at Seattle is handled from two stations, but under a single organization, one station superintendent having supervision over both stations.

Auburn

The operation of Auburn yard of the Northern Pacific is under the direct supervision of the Division Superintendent of that road, who reports to the Terminal Manager. This yard is used by the Northern Pacific for consolidation purposes. Merchandise moving from Tacoma and Seattle to points in the interior is here consolidated in order to secure heavy tonnage per car. The Northern Pacific has a transfer shed and platform in the Auburn yard for handling L. C. L. freight. About seventy-five cars of merchandise per day are handled at this shed and platform.

Tacoma

The terminal yards of the Northern Pacific and the Oregon-Washington Railroad & Navigation Lines and a portion of the yards of the Chicago, Milwaukee & St. Paul have been consolidated into one yard, the terminals of the Great Northern being abandoned. The joint yard is operated under the supervision of the Division Superintendent of the Northern Pacific, which roads performs the switching service. Such Chicago, Milwaukee & St. Paul operations as are not connected with the joint yard are under the direct supervision of the Division Superintendent

of that road. Both these officials report directly to the Terminal Manager at Seattle. The joint yard contains one yard office, and the small C., M. & St. P. yard also has a small office.

The Northern Pacific freight house takes care of business of both the Northern Pacific and the Oregon-Washington Railroad & Navigation Lines, under the supervision of one agent. The Chicago, Milwaukee & St. Paul has its own freight house. The Northern Pacific roundhouse is used jointly by the Northern Pacific Railroad and the Oregon-Washington Railroad & Navigation Lines. There is one passenger station operating at Tacoma, that of the Northern Pacific, its facilities being used by all roads.

Car Distribution

The distribution of cars within the Puget Sound District is made by the car service assistant of the District Director, who is located at Seattle. All freight equipment within the Seattle terminals is pooled regardless of ownership. The empty cars are distributed to terminal lines for road haul by the car service assistant. Interchange reports are required of the terminal organization, these reports being rendered to the terminal lines, which indicate the cars as received at the terminal and also the cars delivered to the terminal lines in departing trains. The demurrage accounts are handled through the general yard office at Seattle.

Thus we have a joint operation within the Puget Sound District under the separate management of the Terminal Manager, who reports directly to the District Director. The properties of the individual railroads have been left intact and their separate facilities have been used as units to make up the general scheme of unified operation. The operation of the Puget Sound terminal district, while apparently presenting insurmountable obstacles, has been worked out in such a way as to make it an ideal one from the standpoint of efficiency and economy. The operations as at present could without doubt be continued advantageously under private control.

MONOGRAPHS

A STUDY OF THE MECHANICS OF CURVE RESISTANCE

By John G. Sullivan

Consulting Engineer, Canadian Pacific Railway

This is a subject that the writer has been interested in for a great many years and as Chairman of Committee XVI—Economics of Railway Location, American Railway Engineering Association, he has had occasion to study several theories on this subject, even to the theory that curve resistance was caused by the friction between the inner wheels and the inside rail of the curve on account of the obliquity of traction. The majority of theorists, however, give centrifugal force the center of the stage as one of the main factors in this problem.

The Economic Theory of Railway Location, by A. M. Wellington (6th edition) states in paragraph 296, pp. 283 and 284: "The coning now put in wheels is chiefly useful as a prospective provision for wear; and experiment shows that whether the wheels be coned or not, the tendency of *any rectangular wheel-base is to roll very nearly in a straight line.*" This statement appears logical, but unfortunately it is not entirely true, as the writer will try to prove further on. What Mr. Wellington said years ago is still true, paragraph 292, page 281: "Curve resistance has never yet been exhaustively investigated, and our knowledge is in several respects deficient." The late A. M. Wellington seemed to have the most accurate knowledge of the actual conditions of any authority that the writer has ever read, still we cannot agree with some of his conclusions. For instance, paragraph 314, page 294, in speaking of the conditions that exist as shown in his Fig. 31, same page, states: "The consequences of this condition of things are these: first, the disproportion in the diameter of the wheels; *hence the necessary longitudinal slipping, and hence the curve resistance, is materially increased.* If the increase of radius of wheel be 3/16-inch, the *extra distance slipped through* per station of 100 feet by one wheel will be 1.16 feet." Now the writer believes, which he hopes to prove later, that the emphasized statements are exactly opposite to the facts.

Referring to the theory of centrifugal force in this problem, the writer believes that with track having anything like the correct elevation of the outer rail, this is a very minor factor, that as far as the action of centrifugal force on the car body is concerned the result is simply the placing of more or less weight on the outer rail. Centrifugal force acting on the truck may affect the problem to a slight degree.

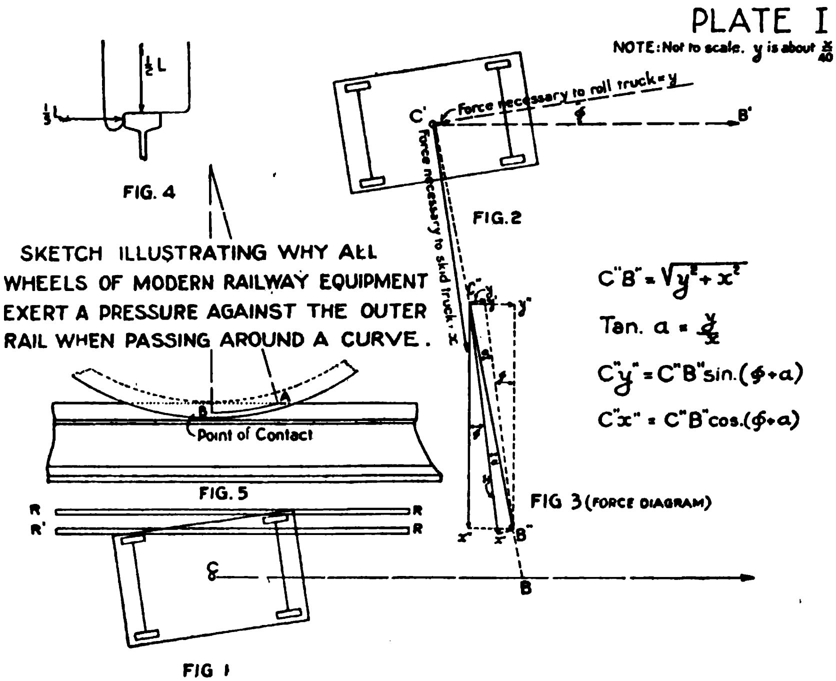
Regarding the theory of obliquity of traction, this theory, of course, is absurd, for we have on all railroads positive evidence that the flanges of railway wheels cut away the head of the outside rail, while the evidence is plain that there is no flange wear against the head of the inner rail.

The writer has no doubt that this obliquity of traction has a slight effect on the problem, but that this effect is very small is proven by the fact that a locomotive will practically push as many cars as it will pull. In the first place, the obliquity of traction is forcing the equipment against the outside rail in addition to the other force that make the flanges run against the outside rail, while in the latter case the obliquity of traction is pulling the cars away from the outer rail, therefore, if this force was of any great moment, doubling the effect as in the cases mentioned would be more apparent than it proves to be in actual practice.

The writer is well aware of the fact that it is easier to tear down than to build up and the reader will rightfully say, "What is the good of all this criticism unless we can get some constructive material in its place?" To this the writer will have to admit that he cannot offer any scientific formulas that will satisfactorily explain actual curve resistance as we find it in practice. On the other hand, the writer has never seen in print a statement of what he considers the real reason why all outer wheels of railway equipment exert a pressure against the outer rail on a curve. Wellington states it is the rigid rectangular shape of the wheel-base. Those who pin their faith on the centrifugal force theory would make you believe that the wheels press against either the inside or outside rail, depending on the elevation of the outer rail in reference to the velocity; this we know from experience and practice is not true.

The reason all wheels of modern equipment, regardless of degree of curve, speed of train or elevation of track (within reasonable limits) exert a pressure against the outer rail on a curve, is the fact that *a revolving cylinder tends to rotate in a straight line perpendicular to the axis of rotation;* or to reverse this proposition, *to make a revolving cylinder move in a direction not parallel with a line perpendicular to the axis of rotation requires a greater force than the force necessary to rotate the cylinder in a straight line perpendicular to its axis of rotation.* If our wheels were manufactured with flat treads and vertical flanges on account of their being fastened rigidly to the axle, we would have in practice our equipment carried on revolving cylinders with a portion of the cylinder cut away, and if this were the case I believe it would be possible to devise formulas that would correctly represent actual amount of curve resistance. The writer's ideas can be made clearer by reference to Plate 1, Figs. 1 and 2, which represents a four-wheel rectangular truck with wheels rigid on the axle, rigid wheel base and flat tread. The smallest force necessary to move this truck is the one required to move it on a straight line perpendicular to the axis of rotation of the wheels. The force necessary to move such a truck parallel to the axis of the wheels would be the weight of the truck multiplied by the coefficient of friction between the truck wheels and the surface on which it was skidded. If we represent these two forces by y and x, respectively, and assume that we have a power at B

moving in a straight line *CB*, such as a locomotive on a truck and that this locomotive was attached by a flexible rope or cable to the center pin of the truck at *C′*, the connection being made by swivel and other details so perfect that the truck would maintain the same relative position while it was being moved along line *C′B′*, the trucks would take the position so that the tangent of angle (a) made by the cable *C′B* and a line parallel with the axis of the trucks passing through *C′* would be constant and equal to $\frac{y}{x}$ and the strain in the cable would be equal to $\sqrt{y^2+x^2}$ and resolving this force *C″ B″* into two forces, one



parallel to the line *C′B′* and the other perpendicular to this line, we get the actual pull in direction *C′B′* equal to *C″y″* and the pull on the locomotive at right angles to the track is equal to *C″x″*; if we give a definite value to angle ϕ it would be easy to obtain actual values of x and y. Instead of allowing the truck to take the position indicated in Fig. 2, if there were small cleats (*R.R.* and *R′R′*) nailed on the flat surface on which it is assumed the truck is moving as indicated in Fig. 1, neglecting the amount of friction between the wheel and the cleat, the pull on the locomotive would be *C″y″* and the pressure against the cleats would be *C″x″*. Now, instead of having a straight line *CB*, if we

have a curve line passing through *C* we could replace the two cleats by a curved rail and have almost identical conditions. If we then had a flat tread wheel and vertical flange as shown in Fig. 4 with correct elevation, half the axle load would be on the outer rail and the horizontal pressure against the outer rail would be the total load on the axle multiplied by the coefficient of friction necessary to skid the wheels. This force acting against the flange of the rail, something in the position of the line *AB* shown in Fig. 5 might be susceptible of a mathematical solution and we could no doubt get formulas which would correctly represent curve resistance as we know it to exist. Now everything that has been said in regard to the truck in Fig. 1 and Fig. 2 would be actually true if applied to a single *set of wheels*.

It is generally conceded that curve resistance amounts to approximately 0.8 lbs. per ton of load per degree of curvature. A great many believe that the major portion of this resistance consists in the skidding of the wheels in a longitudinal direction on account of the difference in length of the inner and outer rails. If this skidding actually took place the difference in length between the inner and outer rails on a one-degree curve for a distance of 100 feet being approximately 1 inch: one-half the load on the wheels would have to be skidded 1 inch or if the skidding backwards and forwards were equal, the entire load would have to be skidded ½ inch, and even assuming a large coefficient of friction for a moving body, say 22 per cent., a little calculation will prove that the work done in this skidding would only account for ¼ of the 0.8 lbs. mentioned above.

In order to check the writer's ideas that the greater portion of curve resistance was caused by the pressure of the wheels against the outer rail, caused by the tendency of a cylinder to rotate in a line perpendicular to its axis as mentioned before, the writer had a long 8° 10′ curve leading off the yards in Winnipeg carefully measured up. He then calculated what diameter the inner and outer wheels should be, so that in passing around this curve if the theory of coning proved correct there would be no flange pressure on either rail, in other words, the diameter of the wheels was made directly proportional to the length of the two rails on an 8° 10′ curve. These wheels were turned with a standard flange but with a flat tread; they were put under C. P. R. steel flat car 311074, 36′ 10″ long, 5″ x 9″ journals, a simplex truck frame, center to center of axles 5′ 4″, center to center of trucks 26′ 7″ Susemil side bearings. The tare of this car was 31,200 lbs., live load 99,000 lbs. of steel rails. The first experiments made with this car were with the idea of testing the tractive force necessary to move the same.

The writer asked the Mechanical Department to rig up a system of levers with a spring balance that would be capable of measuring the tension necessary to pull this car on a level straight track. The Mechanical Department, however, were of the opinion that we could get better results by using the dynamometer car with some alterations. This car has a piston free to move in a 16-inch diameter cylinder filled

with oil; this piston is connected with a draw bar by a shaft 4 in. in diameter and this shaft is so packed that no oil will leak with a draw bar pull up to 60,000 lbs. The oil from both ends of this cylinder is piped to a small recording machine in the cupola of the car. This recording machine has pistons with ½-inch end area. This portion of the machine was changed to a piston with 2½ square inch end area in order to enlarge the scale to read the small pressure that would be produced in hauling a single car.

Six or seven tests were made hauling this loaded car over this 8° 10″ curve which was over 1,000 feet long, then over a distance of 2,000 feet on straight level track, thence over a short 5° curve in the reverse direction. It was apparent from the start that on account of the packing our machine was not delicate enough to accurately measure small pressures. The writer, therefore, abandoned the idea of attempting to get definite figures in pounds per ton with this machine, but the results proved conclusively what the writer expected, viz., that the resistance on the 8° 10″ curve was only 50 per cent. to 60 per cent. of the resistance on straight track and when the car was pulling over the 5° reverse curve, which was really too short to get a constant pressure, being less than 150 feet long, the indicator went up 10 to 20 per cent. over what it had been on straight track.

A very instructive lesson was obtained through a mistake that had been made. In going around the long 8° 10″ curve at all speeds, varying from 5 to 20 miles an hour, it was noticed that the trucks would run first against one rail and then against the other. It was further noticed that the conditions were the same at every trial, that is, the location where the trucks would press against the outer rail were the same. The writer sent for the Resident Engineer who had instructions to measure the curve and he reported: "I thought you wished to know what degree of curve would best fit this location, the curve is not true, it must be thrown 5 or 6 inches in or out at several points". This, of course, was the explanation why the trucks did not run true. We simply had a series of compound curves, some sharper and some flatter than 8° 10″; the elevation at this time was about 3 inches.

The next test consisted of pulling C. P. R. flat car 310173, similar in all details to 311074, except that the former had standard trucks which were in very good shape. The dynamometer car results indicated, as we expected, that the resistance on straight track was only 40 per cent. to 50 per cent. of the resistance on the 8° 10′ curve. The tests were then stopped, the curve was properly lined and surfaced and the elevation reduced to 2 inches. At a later date exactly the same tests that were mentioned above were repeated. The packing was somwhat loosened up and more accurate results obtained but still not accurate enough to be given as a measure of either curve or track resistance. While the relative resistance of straight versus curved track was quite constant the indicated pressure of different tests on the same track varied too much to justify even taking the mean of the number of tests we

made as a measure of track resistance. The results, however, prove conclusively that the resistance offered on an 8° 10′ curve to the car with the special wheels was only 50 per cent. to 60 per cent. of the resistance on straight track, and, as you would expect another similar car 310026 with a total weight of 129,000 lbs. with nearly new standard wheels the resistance on straight track was only 40 per cent. to 50 per cent. of the resistance on the curve, but the most important feature of this test was the fact that the trucks under car 311074 while going around the 8° 10′ curve never pressed against the head of either the inner or outer rails but ran exactly as true as the ordinary truck runs on a straight track and this was true regardless of the speeds, from 5 to 25 miles an hour, thus proving at least to the writer's mind that the rectangular shape of wheelbase, especially so for the short wheel-base of a freight truck, has very little or nothing to do with causing the pressure of the wheels against the outer rail.

The next test that was made was one to determine, if possible, which wheels of a railway car do the skidding and the amount thereof. The writer has always been of the opinion that on account of the extra horizontal pressure of the leading wheel of a truck against the outside rail, that unless the vertical pressure on the inner rail was largely in excess of the vertical pressure on the outer rail, that there would be very little or no skidding of outer front wheel of the truck. The writer is convinced that this is true, also that there is no backward skidding of the inner front wheel which was more than was at first expected.

Referring to Plate II, there are five figures indicating various conditions that we meet with in general practice. Fig. 1 shows standard wheels on C. P. R. standard 85-lb. rail straight track. The circumference that is measured in mating wheels is indicated as on "wheel diameter line," 1 inch from the base of flange and about 1 inch from the end of the one-in-twenty taper, that is, the small radius of the wheel at the end of the one-in-twenty taper is about 0.05-inch less than at the point of measurement, making the small diameter about 0.10-inch less than at the point of measurement, that is, the circumference of the wheel at this point is nearly a ⅓-inch less than at the point of measurement. The other figures are self-explanatory and indicate conditions that do exist, as any investigator can prove for himself by taking small gage copper or soft iron wire and placing it transversely across the rail under a moving wheel on a curve. The condition shown in Fig. 5 will not, of course, be constant, for the reason that the outside wheel in that case is rolled on such a very large diameter that it would soon slip away from the rail entirely it it could be supported on this large diameter, but what takes place in this case and which can be verified by watching the leading inner wheel of a truck traveling on a worn rail (as is indicated) a nosing motion will be found, that is, the wheel is constantly moving with a jerky motion. This feature can be very well observed by riding on the pilot of a locomotive with a sharp

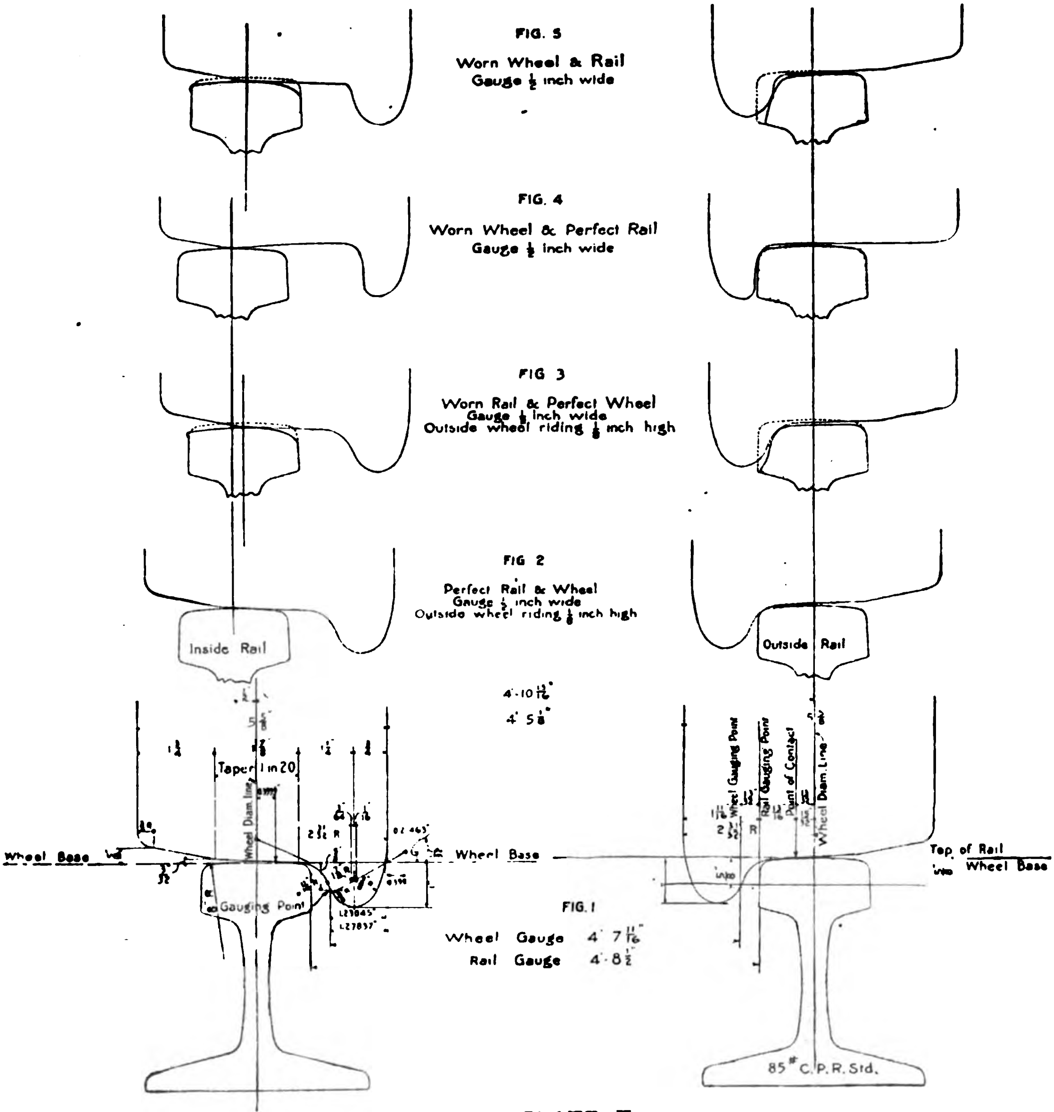


PLATE II

SHOWING POSITION OF CAR WHEELS ON TRACK UNDER VARIOUS CONDITIONS

flange pony truck whenever the same is going over a track where the outer rail of a curve is badly worn.

The writer has purposely called the attention of the reader to Plate II and the various figures thereon, to prepare his mind with an explanation of the apparently contradictory evidence obtained in some tests made with a view of attempting to measure the amount of skidding of the wheels. C. P. R. 310016, flat car, gross weight 129,100 lbs., was run at a speed of about four miles an hour a distance of about six hundred feet over the above mentioned 8° 10′ curve; the car was started from rest, each wheel marked at point of contact with rail. It was then moved north until the leading wheel had made 70 revolutions, the revolutions on all the other wheels were counted and measurements taken to show how far they would have to go to complete the 70 revolutions. The car was then run in the reverse direction. Table I gives the results of these measurements, in column 2 actual distance traversed by each wheel in making 70 revolutions is recorded, in column 3 is recorded 70 times the circumference taped in the field close to the flange. It should be noted here, however, that only the wheels on the one side of the car were taped. It was taken for granted that they would be properly mated as they showed no flange wear that would indicate they were not properly mated. Column 4 gives the difference or apparent skidding distance of each wheel if the wheels had been running on the diameter as measured. After the test was made, the car was sent to the shop, the wheels taken out and officially taped. In column 5 we show 70 times the circumference of this official taping and in column 6 the difference between 70 times the circumference and the actual difference traveled on the rail. Now we started out with the idea that there would be very little or no skidding of the outside leading wheels of any truck. If you will note, however, the outer wheel's axle No. 1 and 3, columns 4 and 6, the car going north and also the outside wheel on axles 2 and 4 in column 4 and 6 when the car was going south, one would be apt to say that these were the wheels that did the skidding. As a matter of fact, however, from experiments made with a very soft fine wire the writer is convinced that the outer leading wheels on a truck take the position indicated in Figs. 2, 3, 4 and 5, Plate II, and that there is absolutely *no backward skidding of the inner leading wheels of any railroad truck in rounding a curve. Any skidding that may take place in the wheels of the leading axle is equal and in a forward direction,* taking the very small amount of indicated backward slip of the inner wheel axles 1 and 3 going north and 2 and 4 going south, column 4, where we know the taping was taken on a larger diameter than the one the wheels were rotating on and taking the figures in column 6 for the inner wheels of the leading axles of the trucks, which indicate a positive forward slip of the inner wheel, when we know that the diameter on which the wheels were rotating could not have been larger than the diameter on which measurements were made, would indicate that the outer wheel was pressed so hard against the outer rail that the resistance against free rotation was so great that the result is that both wheels were actually

skidded a short distance forward. It is well known that a speedometer attached to the rear wheel of an automobile will register a greater amount of miles than one attached to the front wheels of the same diameter. If we reversed this situation and there were obstrutcions placed in the way of a wheel equal to the force exerted in driving the car we would expect this wheel to show a loss of distance equal to the gain in distance shown by speedometer on the rear wheel. It appears to the writer that this forward skidding of both wheels of leading axle is quite natural.

It should be noted here that five or six rails were taken from the inside of the car and placed on the outside in an attempt to balance the vertical pressure on the two rails of the curve on account of 2 inches being too much elevation for a speed of four miles per hour. However, there was not enough rails moved to entirely overcome the effect of the 2-inch elevation.

Now, if the reader will again look at Figs. 2, 3, 4 and 5, he can see how easy it is to get a wheel to ride an ⅛-inch or more high, that is, increase the diameter on which the wheel rotates by a ¼-inch and that is all it requires to account for the extra 4.862 feet.

Now, making a study of all the outer rear wheels of the trucks it is very plain to the writer, as observation and experiments proved, that these wheels press against the outer rail and ride on a larger diameter than the official taping indicates but not sufficient to overcome skidding entirely, that is, there is some skidding of the inner wheel of the rear axle of a truck, although the amount is rather small. This conclusion is directly opposite to that stated under paragraph 302, page 285, The Economic Theory of Railway Location, by Wellington. On a test with C. P. R. flat car 311074 with the special wheels on about 600 feet of straight track, measurements were made for only the leading truck and it was found that there was about 3 inches slip on the larger wheel of the leading axle and about 10 inches on the larger wheel of the rear axle. These amounts were reversed when the car was run in the reverse direction and as the difference in the diameter of wheels, the *threads being turned flat,* amounts to about 4.2 feet in going a distance 603 feet, the writer was convinced that the small amounts of slip mentioned, 3 inches and 10 inches, respectively, was accounted for by the fact that the wheels of smaller diameter in their attempt to mount the rail, rode on a larger diameter and that there was very little if any slipping of the smaller wheels.

Similar tests as to that taken with C. P. R. car 310016 had been previously made with C. P. R. flat car 310173, they confirmed exactly the results obtained with C. P. R. car 310016, but the car got out of the yard before the wheels could be officially taped and the results made of that car are not reported. Another test on a side track laid parallel and on the outside of the 8° 10′ curve, track laid with 56-lb. steel, C. P. R. car 310016 loaded as in the experiment recorded gave practically identical results as those recorded.

The writer's object in giving this matter to the public is to revive interest in this subject, bring out discussion, and if possible get more information on this important subject. It is only when the actual causes of trouble are really understood that the proper remedies can be applied. The second reason is to call the attention of operating officials of railways to the fact that it is a waste of fuel to haul cars over railways. the wheels of which are not running true. It is the writer's belief that over 75 per cent. of the wheels that are taken out of service on account of sharp flanges have only one wheel on an axle with a sharp flange. This is caused either by poorly mating the wheels or by being placed in trucks that are not properly squared. Whatever the cause, this matter should be given more attention by mechanical and operating officials.

The writer is convinced that the greater portion of curve resistance is caused by pressure of the flange against a single rail; therefore, the mating of wheels or setting up of trucks not properly true that cause the flange on one wheel of an axle to wear sharp is not only shortening the life of the wheel, but is costing the company considerably more money to acquire this undesirable result.

The following is a summary of the writer's conclusions:

(1) All outer wheels of railway equipment exert a pressure against the outer rail when rounding a curve.

(2) The cause of this pressure is the tendency of a cylindrical body to rotate in a straight line at right angles to the axis of rotation.

(3) That there is never any skidding of either wheels of the leading axle of a truck unless it is a forward skidding of both wheels caused by the resistance to rotation being great enough to cause a slight retardation to rotation which results in an apparent forward skidding.

(4) That there is no skidding of the outer wheel of a rear axle, that in general any skidding that does take place is on the inner wheel of the rear axle.

The reader will naturally ask, if there is very little skidding of wheels, wherein lies the considerable resistance offered by curves, that we know from experience actually exist. *That is the problem the writer started out to try and solve,* but as stated at the beginning, he cannot give any reasonable formulas. The writer had formulas for the case of flat tread wheels and vertical flanges that worked out beautifully close to the accepted amount of resistance offered by curvature in these formulas: however, co-efficients of friction were taken rather large for bodies actually moving on each other, and the horizontal pressure against the outside rail was assumed to be ⅝-inch below the top of the flat top and vertical side of rail as shown at *B*, Figs. 4 and 5, Plate I, but what is the use of giving formulas for conditions that we know do not exist?

The only thing the writer can offer is his opinion which is, that the major factor in the resistance offered by curvature is caused by the *flanges of the outside wheels striking the outside rail at an angle instead of rotating in lines parallel with the gage side of the head of the rail.* Anyone who doubts the reasonableness of this opinion can ask any old-timer what his experience was in the days before gasoline, in pumping a velocipede over the road with the leading wheel not set true and especially when it was set to hug the rail.

TABLE I.

Results of Test to Determine Amount of Slip C. P. Flat Car 310016 Loaded with Steel Rails—Gross Weight, 129,100 Lbs.—8° 10′ Curve —Outer Rail Elevated 2″—Speed About 4 Miles Per Hour.

1	2		3		4		5		6	
Axles Numbered 1-2-3-4 From North To South / Axles No.	Distance on Rail Measured in Feet Travelled by Wheels Making 70 Complete Revolutions		70 Times Circumference of Wheels in Feet Taped in Field Close to Flange		Difference Between Distance Measured on Rail and 70 Times Circumference		70 Times Circumference of Wheels in Feet as Officially Taped After Test 1" From Base of Flange		Difference Between Distance Measured on Rail and 70 Times Official Taping of Circumference	
Car Moving North	Outer	Inner	Outer	Inner	Outer	Inner	Outer	Inner	Outer	Inner
No. 1	605 88	601.68	602.29	602 29	+3.58	−0.61	601.01	600.83	+4.87	+0.85
No. 2	605.58	601.39	605.21	605.21	+0 37	−3.82	604 11	604.11	+1.47	−2.72
No. 3	605.92	601.73	602.29	602.29	+3.63	−0.56	601.38	601.01	+4 54	+0.72
No. 4	605.46	601.27	603.02	603.02	+2.44	−1.75	602.11	602.29	+3.35	−1.02
Car Moving South										
No. 1	604.67	600 48	602.29	602.29	+2 38	−1.81	601.01	600.83	+3 66	−0 35
No. 2	608 88	604 68	605.21	605 21	+3.67	−0 53	604.11	604.11	+4.77	+0.57
No. 3	604.63	600.43	602.29	602.29	+2.34	−1.86	601 38	601.01	+3.25	−0 58
No. 4	607 08	602 89	603.02	603.02	+4.06	−0.13	602.11	602.29	+4.97	+0.60

The writer wishes to acknowledge with thanks some valuable criticisms on this subject by I. P. Church, Professor-Emeritus, of Cornell University, Ithaca, New York.

PRACTICE IN THE DESIGN OF CONCRETE FLOOR SLABS AND FLAT TOP CULVERTS

By Geo. H. Tinker
Bridge Engineer, New York, Chicago & St. Louis Railroad

Several years ago the author addressed a letter to Bridge Engineers connected with the various railroads of the country, asking the following questions:

(1) In the designing of flat top culverts or reinforced concrete floor slabs, what is your practice in considering the distribution of axle loads—longitudinally, transversely and vertically?

(2) In connection with the above, what impact allowance do you use?

(3) Can you refer to any investigations or data bearing upon this subject?

The response to this questionnaire was gratifying and fairly representative of the practice of railroad Bridge Engineers.

The author has made an abstract of the replies and added a summary and short analysis of some of the salient points.

The matter is of present interest in connection with the investigation of the distribution of load through ballast. It is, therefore, deemed advisable to make the information available by publication in permanent form. The serial numbers in the first column of the summary refer to the replies having corresponding numbers.

ABSTRACTS OF REPLIES.

1.

When we first commenced designing our reinforced concrete boxes we worked out a scheme for finding what would be the arch effect in the earth fill over the top of the box, and our calculations showed that at a point varying from 10 to 18 feet below the base of rail, the arch effect from the fill would carry all of the weight of this fill.

In making our calculations for the slabs we finally settled down to assuming for dead load the weight of track and ballast; also, the weight of a layer of earth ten feet deep. This in addition to the weight of the slab itself made up the dead load. We followed this same scheme in designing reinforced concrete slabs where the top of slab received the ballast direct.

For ordinary boxes we do not count on allowing the upper surface of top of box to be closer than 24 inches from base of rail. Where the slab receives the ballast direct, we have usually added as much as 40 per cent. to the live load moments for impact. In the case of boxes the heavy dead load assumed in the 10 feet will provide all that is required in the way of impact.

I do not know of any investigations on this line which have been published. I tried to find something of the sort several years, but did not succeed.

2.

We are not using this type of construction, except in reinforced slabs on deck plate girders.

In cases of this kind, it has been our practice to assume the axle loads uniformly distributed over the track. This is perhaps somewhat in error, but as the slabs have longitudinal rods as well as transverse rods, we believe that this assumption is entirely safe. The axle loads are assumed distributed over a width of five feet on either side of the center line of track. For our flat top culverts we use I-beam construction encased in concrete, using a straight impact of 50 per cent. This is our practice at present, and, of course, will be changed if the impact tests which are being made by the American Railway Engineering Association develop the fact that the impacts assumed are not sufficient.

3.

We have recently designed several bridges with reinforced concrete slabs in which we placed the center of gravity of the axle loading of Cooper's E-60 locomotive over center of span; transversely, we considered the loading distributed over a width of 10 feet; vertically, we designed

the slab of sufficient thickness to take care of the compressive stress. We allowed 100 per cent. impact.

4.

(1) Consider the axle load distributed longitudinally by the rail over a distance of about three feet, transversely, the length of a cross-tie plus the depth of the roadbed.

(2) When the roadbed is five feet deep or more, no addition is made to the live load for impact; for depths less than five feet about 75 per cent. is added for impact.

(3) I regret that I am unable to refer you to any investigations or data bearing on this subject.

5.

In designing flat top culverts we use our standard live load with full impact and include in the dead load five feet of fill. Culverts so designed are used under any height of fill on the assumption that as the depth of fill increases the lateral distribution of the load compensates for the increased height of the fill and our experience of several years warrants our adherence to this practice.

For concrete floor slabs, such as are used in our concrete pile trestles, the impact is taken at 25 per cent. on each rail and distributed transversely over the entire width of the slab. This is true also of the distribution of the entire load, as it is quite inconceivable how any other condition can exist.

This whole matter of impact, however, is so bound up with the matter of unit stress which is allowed that the two must be considered together. For instance: if we assume an impact allowance similar to that recommended by Committee XV, American Railway Engineering Association, which is designed to cover all the effect of moving loads, we should then employ a unit stress which is as high as should be considered in designing, that is to say, about 50 per cent. of the elastic limit. As a matter of fact, our practice is to use a smaller impact and lower unit stress, our unit stress in steel being about one-third of the elastic limit.

I know of no data at present available regarding impact on reinforced concrete structures. Investigations are being made, however, and data will probably be available in the near future.

6.

In case the ballast on the culvert top exceeds two feet in depth, we design for a live load of 12,000 lbs. per linear foot of track, distributed over eight feet transversely to the track at the base of rail, and spreading laterally six inches per vertical foot to the bottom of the slab. This gives a lateral spread of three inches per foot on each side. For dis-

tribution of live load transversely to the track on concrete ballast floors for steel girders, we assume the live load to be either concentrated under the rail or distributed uniformly along the tie, using whichever assumption gives the greatest moment. We assume the maximum wheel loads distributed longitudinally over the full length of our standard slab for steel girders; this length is three feet seven inches. In the case of our trestle slabs which have a standard width of 13 feet, we assume the load on the track spread over the full width of the slab, and to be concentrated under the wheels in a longitudinal direction.

An impact allowance of 50 per cent. is added to all live loads. The impact is not considered, however, in figuring the area of foundations.

Regarding your third question. I find I have no references at hand on the subject of the spread and distribution of live load through earth embankment.

7.

I will advise that in designing flat top culverts where the bank is 15 feet or over, we consider the axle load distributed longitudinally over five feet. We assume that the load is distributed transversely at the base of rail for a distance of ten feet, spreading from there to the top of the culvert six inches transversely to each foot in rise. In banks of this height we allow no impact. For banks under 15 feet in height we have allowed 50 per cent. impact distributed in the same manner as the live load. In the case of a culvert or an arch coming so close to the track that we are unable to get anything more than the ballast on top of the cover, we have assumed the live load to be distributed over ten feet with an impact of 50 per cent. We have assumed the dead load to act vertically on the cover of the culvert.

On I-beam slabs where ballast only is placed beneath the tie we assume that the steel carries the entire load and we apportion our steel for the actual moment produced by the loads, adding an impact of 50 per cent.

I cannot refer you to any investigations or data bearing upon this subject and believe that every road has its own method of distributing the live load, as well as percentage of impact.

8.

Our standard plan is based on the moments from Cooper's E-60 loading, with full impact by the 300 formula. This produces a unit stress of 18,000 lbs. in the steel and the reinforcement is one per cent. The live load is considered distributed over a width of ten feet laterally. This answers your first and second questions.

As to the third question, the only thing I can think of outside of the impact experiments, with which you are familiar, is the paper by Thos.

H. Johnson on the distribution of the live load by the ballast. This was published as a Bulletin by the American Railway Engineering Association two or three years ago.

Referring further to questions one and two. We have not made a practice of reducing the impact with an increase in depth of fill over the culvert, although I think such a reduction would be proper where the fill exceeds five feet. Our flat top culverts are usually close under the rail without much fill over them.

We have also designed structures on a basis of 1800 lbs. per square foot or 18,000 lbs. per linear foot without impact and with unit stress of 15,000 lbs. in the steel.

You spoke of some of the Chicago track elevation work having been figured for a lateral distribution of the full width of the slab 13 feet. I think this is fair for deep slabs, as undoubtedly the lateral distribution secured increases with the depth of the slab. My present idea is to revise our practice to consider a lateral distribution of eight feet plus the depth from the bottom of the tie to the bottom of the slab. This would make a width of 11 feet for a two-foot slab with one foot of ballast or 12 feet for a three-foot slab with one foot of ballast.

9.

(1) Longitudinally, the axle loads are considered as uniformly distributed over a distance of three feet.

Transversely, they are considered as uniformly distributed over a distance equal to the length of the tie, or in other words, eight feet.

Vertically, they are considered as acting straight down, the arching action of the earth being neglected.

(2) Impact is assumed at $L \times \frac{L}{L+D}$, where $L =$ live load stress, and $D =$ dead load stress.

In this connection, however, we design our culvert, considering impact for a minimum fill of three feet. Then we do not change the section required by this assumption until the dead load plus the live load (neglecting the impact) exceeds the dead load plus live load plus impact, for the first condition, or in other words, we find out what the impact amounts to converted into pounds of fill.

In a case I am working on now, for a four-foot opening, I added 16 feet of fill before I changed the section of slab required.

(3) I do not know of any data or investigations on this subject.

10.

Our standard flat top reinforced concrete culverts, which vary from four-foot to sixteen-foot spans, are designed for a uniformly distributed

load of 2,000 lbs. per square foot. Our slab construction for carrying ballasted track is designed for Cooper's E-60 loading with 50 per cent. of impact obtained from formula $\frac{S\,300}{L + 300}$. This slab is to be built near the site of the bridge in one piece 14 feet wide for single track. The load is considered uniformly distributed throughout the width of the slab and the bending moments and shears for cross-section are figured on the basis of wheel concentration. The transverse rods are figured on the basis of this load distributed uniformly.

11.

When the crossing is at right angles to the tracks, or the main reinforcing is parallel with the tracks, we use the maximum bending moment for the given span, calculated from the wheel loads. The spread of this load transversely depends upon the width of the slab that can be cast at one time. Where slabs less than nine feet in width are cast in a curing yard, and are later placed on the supports, the live load is spread over a width of nine feet. For slabs over nine feet in width, the live load is spread the full width of the slab up to 13 feet wide.

When the span is on a skew, or the main reinforcing at an angle with the tracks, we use a live load of 1,200 lbs. per square foot. This is the same as spreading axle load of 55,000 lbs. over a transverse distance of nine feet and a longitudinal distance of five feet.

Heretofore we have been using 12,000 lbs. allowable unit stress for the steel, and 600 lbs. for the concrete, no impact added; but recently we have changed and are now using 17,000 lbs. allowable for the steel and 700 lbs. for the concrete, with 50 per cent. of the impact obtained by multiplying the live load by the quotient of the live load divided by the sum of the live and dead loads.

With regard to investigations on this subject, would refer you to Bulletin No. 28, of the University of Illinois Experiment Station.

12.

(1) Distribute axle load at right angles to track over a distance of nine feet, plus one-half the distance from the bottom of tie to the culvert top.

(2) Distribute axle load uniformly lengthwise of track, when top is equal to or greater than six feet, from bottom of tie.

(3) When bottom of tie is equal to or less than two feet from top of culvert, consider the distribution of axle load uniform over a distance of 24 inches lengthwise of the track.

(4) For an intermediate point, distribute proportionally between the limits assigned by Rules (2) and (3).

Impact, 50 per cent. when ties rest on culvert top or six inches of ballast, and nothing when fill equals or is greater than two times the clear span of culvert. Proportion between the above limits.

13.

(1) The distribution of axle loads, both longitudinally and laterally, depends upon the amount of ballast and embankment that can be placed as a cushion between the top of slab and the underside of tracks, longitudinally for single openings the distribution over 20 feet is not needed; for more than one opening of 12-15 ft. or over, other axle loads would follow driver load of engine.

(2) The impact upon the slab is greater, the smaller the ballast and embankment.

I should adopt a graded system of distribution and impact assuming a line to be single track the axle load not less than 60,000 lbs., four axles spaced five feet centers or 15-foot wheel base.

For ballast and embankment not over two feet, assume width of slab three feet per rail and length 20 feet.

For ballast and embankment not over four feet, assume width of slab 5 feet per rail and length 20 feet.

For ballast and embankment not over six feet, assume width of slab 12 feet for two rails and length 20 feet.

For ballast and embankment not over eight feet, assume width of slab 14 feet for two rails and length 20 feet.

For ballast and embankment ten feet, assume width of slab 16 feet for two rails and length 20 feet, etc., using weight per square foot of slab in calculating sections.

For double track I should follow the same system of distribution.

In regard to the impact upon these structures, I should assume 50 per cent. impact sufficient for slabs with ballast and embankment from two to six feet in depth; below six feet I should assume that a reduction is permissible, lessening the percentage of impact gradually from six to twelve-foot embankment to 25 per cent. and from 12 to 18-foot embankment a gradual reduction from 25 per cent. to zero.

In my judgment, for ballast, including embankment higher than 18 feet, the weight of the embankment plus the weight of the slab is so heavy as compared with the distributed moving load that no impact is required.

The embankments over structures should be packed as deposited; if this is impractical, I should cut the line of batter of distribution, making it three inches per foot instead of six inches.

In regard to your third question, I wish to state that I have never seen any investigations or data published on this subject.

14.

(1) In designing flat top culverts, we have based our calculations on the following general assumption with reference to loading: Dead load—the actual weight of the earth covering, which in section is assumed to be a trapezoid whose base is equal to the span of the culvert, and the sides on a slope of one-half to one. Calling the span "S" and the height of the fill "H," the top of the trapezoid will be equal to "S" plus "H." This is somewhat in excess of the actual conditions, but such a condition will probably exist immediately after refilling over the culvert. When sheet piling or timber is used to retain the earth during construction of the culvert, I think that it will be ample to figure the weight of the earth vertically above the top slab; in other words, the sides of the trapezoid will be vertical.

For live load we use the greatest equivalent load per linear foot of track for a 192-ton consolidation engine. This equivalent load per linear foot of track is reduced down transversely (for single track) on a slope of one-half to one from the end of the ties. In the case of more than one track the equivalent load is reduced down in the same manner as for one track, but in no event should the width be taken greater than the distance between track centers. For example, if the equivalent live load per linear foot of track is, say, equal to 10,000 lbs., the fill over the top of the culvert is, say, 12 feet, and ties 8 feet, the live load on top of the culvert would be 10,000 lbs., divided by 20 or 500 lbs. per square foot.

(2) We make no allowance for impact by increasing the live load, but use lower unit stresses in the material. The fill between the top slab and bottom of tie should not be less than 5 feet. This depends upon the nature of service.

(3) I know of no investigations or data bearing upon this subject. Experience and investigation are very much needed in connection with this important subject.

15.

Our practice is to assume the distribution of axle loads longitudinally four feet. Transversely, we assume that the distribution equals the length of the ties plus the width that the ballast under the tie would give us at a slope of one to one so that with one foot ballast we would have a distribution of 10 feet. We allow the same impact that we allow in our steel bridges.

I cannot refer you to any investigation or data bearing on this subject at present.

16.

It is my practice to consider all loads above the roof of the culvert carried vertically downward. I make an impact allowance of 100 per

cent. for all fills less than five feet and decrease the impact allowance so that there will be none when the fill is twenty feet.

17.

(1) For culverts having no covering beyond minimum depth of ballast, I have made calculations using the wheel concentrations with a transverse distribution of load from one track over a width of 12 feet for the construction shown on the blueprint of the proposed type. You will notice the attempt to secure this distribution by the use of transverse reinforcing rods.

(2) In the design referred to, I contemplated the use of full impact by the formula $\frac{300}{L + 300}$.

(3) I cannot refer you to any investigations regarding this subject. It will be easy to measure deflections and draw conclusions therefrom and I hope to do this at some time in the future. We have made investigations pertaining to trough floors, but these would hardly be applicable.

18.

(1) In designing flat top culverts or reinforced concrete floor slabs our practice is to assume in determining the moment that the axle loads are concentrated at the centers of the axles, and that the load from each track is distributed laterally over a width of eight feet.

We also assume that the loads were distributed vertically at angles of 45 degrees with the perpendicular.

(2) The impact allowance which we use is 100 per cent.

(3) I do not recall any investigation or published data on this subject.

19.

Our practice is to consider the live load as distributed uniformly over the slab and for a width of eight feet for minimum depth of cover. We do not use any impact allowance, and we figure the safe stress on concrete to be 500 lbs. to the square inch, and the safe stress on steel reinforcement to be 15,000 lbs. to the square inch.

Our formula for safe bending in reinforced slabs is that the bending moment which a slab 12 inches wide will carry safely is 1300 H^2, where H is the depth from center of reinforcement to top of slab. We have compared this formula with many actual tests and find it gives good, safe working results. It is not necessary to provide reinforcement longitudinally to take up the expansion if expansion joints are placed about 30 or 40 feet apart.

20.

(1) Distribution of Axle Loads:

Longitudinal ....5 ft.

Transverse ....8 ft.

Vertical, base of rail to top of slab........1 ft.-9 in.

(2) We use full impact, in accordance with Schneider's formula,

$$\frac{300}{L + 300}.$$

(3) No.

21.

It has been our practice in designing slabs to consider the load distributed over a width obtained by drawing a line at 60 degrees, starting at the end of the tie until same intersects top of slab and continuing the line at 45 degrees through the slab. For our standard slab construction, this distributes the load over a width of approximately 12 feet per track.

Where ties are close to the slab, as is the case in our standard construction, we use the same impact percentage allowance which we use in steel stringers, that is 100 minus the span length, divided by 3.

22.

(1) For flat top culverts with the reinforcing extending longitudinally (that is, parallel to the track) I take the bending moment and shear due to our specification loading per track and consider it distributed uniformly over a width of nine feet. This I consider a legitimate assumption, inasmuch as our ties are eight feet six inches long and we have from seven to ten inches of ballast on top of the concrete.

(2) You ask what impact allowances I use. We do not compute the strength of bridges in just that way. For these concrete slabs I take 625 lbs. per square inch for compression on the concrete, and 15,625 lbs. per square inch for the steel, these being assumed to act as dead load, and for all live load, one-half of these figures. Thus the unit stresses for any particular bridge depend upon the ratio of the dead load effect to the total effect, which, if we call this ratio θ, the unit stress in compression on the concrete for any particular case would be 625 divided by (2θ) and for the steel would be 15,625 divided by (2θ). This method is equivalent to multiplying the maximum moment by (2θ) and dividing by the unit stress for dead load as above. The theory, as you can see, is that which assumes that a live load is twice as destructive as a dead load.

23.

In designing such work, we use moment tables as per our standard specification, and consider loads over one track as being distributed over 13 feet width of slab.

24.

(1) Our practice is to consider axle loads uniformly distributed over an area of five feet longitudinally by ten feet transversely to the bottom of the ballast. Through earth fills, from the bottom of the ballast, the distribution is considered transversely at the rate of one vertically to one-half horizontally.

(2) American Railway Engineering Association impact is used. The full impact is allowed on floor slabs which carry the ballasted track without earth fill; and no impact is allowed on slabs on which the depth of earth fill is ten feet below the ballast. The impact with fills varying from zero to ten feet is taken in proportion.

25.

In the design of our slab tops we use a minimum distance, base of rail to top of slab, of 14 feet.

For this class of structure we assume our standard E-55 loading, amounting to 11,000 lbs. per linear foot of deck. We assume that this is uniformly distributed over 10 feet in width, giving a live load of 1100 lbs. per square foot. To this we add 50 per cent. of impact of the live load, which brings the total live load up to 1650 lbs. per square foot.

We figure our slabs as simple beams, supported at each end, irrespective of whether they are single or multiple spans.

For unit stress we use 700 lbs. per square inch for concrete and 14,000 lbs. per square inch for steel.

We consider that a slab designed by the above conditions is sufficiently strong for all heights of bank with sides sloped one and one-half to one. Please note that we have considered the live load distributed over a width of 10 feet plus height of bank (which is a common assumption) and figure the load per square foot the live load plus the weight of the bank at 100 lbs. per cubic foot plus no impact, gives the same result for bank 11 feet high that we get where the ballast rests directly on the slab and 50 per cent. impact is added. In other words, our impact is decreased from 50 per cent. for track directly on slab to no impact for bank 11 feet high. We ordinarily assume that these two points are connected by a straight line, although if you figure out the intermediate points on the above assumption, you will find that it is a parabola but with no very great ordinate.

For banks over 10 feet in height, we assume, and we think justly, that the arching effect of the earth will take care of the additional weight occasioned by the extra height of fill. This results then in our having a uniform thickness and design of slab for all heights of embankment and we think defends this practice on a reasonable basis.

In reference to bars used, we prefer a deformed bar in all cases where the bond between the concrete and steel is of importance or wherever the shear strains are of any importance. We prefer a medium steel, say, 60-65,000 lbs. per square inch ultimate strength, but with as

high elastic limit as possible, preferably not less than 40,000 lbs. We prefer such deformed design that no sharp angles are introduced into the concrete from which cracks may originate in the concrete; in other words, we prefer that all corners in the concrete be filleted, as is found good practice in making of castings or any other semi-friable material.

I would say that our practice as above stated has been more or less completely in force for some years and that we have had no example of failure through any other cause than imperfect mixing or workmanship. We further feel pretty safe in our assumptions as to unit stresses and also think that we have a sufficient margin for increase of power to take care of our needs for some considerable time.

26.

In general, in designing reinforced concrete box culverts for E-50 loading, I assume a live load of 10,000 lbs. per linear foot of track distributed laterally over a width of 2 H plus 5, H being equal to the height of the fill above the top of the concrete slab. I omit the weight of track, figure the slabs as simple beams and figure the entire load of the earth fill over the clear span of the slab at 90 lbs. per cubic foot.

In regard to impact, for a depth of fill of 18 inches from base of rail to top of culvert, I figure full impact in accordance with the formula, I equals 300 divided by L plus 300, I being the per cent. of live load and L the clear span of the slab. For a depth of 12 feet from base of rail to top of culvert, I consider this impact reduces to zero and figure proportionately for intermediate depths.

All calculations for the strength of concrete slabs are figured in accordance with the formulas developed by Burr, considering that the strain in any fiber of the concrete is proportionate to its distance from the neutral axis.

I am aware that the assumptions for distribution of live loads and amount of impact would be difficult to defend, but in view of the uncertainty as to the actual amount of impact on any structure from the live load, the added uncertainty and general factor of safety in the design and construction of reinforced concrete, I consider these assumptions amply safe.

27.

(1) The slab is designed for wheel loads just in the same manner as a steel girder except that no consideration is given to longitudinal and transverse stresses.

(2) The impact allowed is as follows: $I = \frac{L}{L+D} \times D$, in which D = dead load, L = live load, and I = impact stress to be added.

(3) I do not know of any investigation or data bearing on the subject.

28.

(1) In designing flat top or reinforced concrete floor slabs, we are using for live load Cooper's E-50 in the following manner: Assuming the axle load of 50,000 lbs. as distributed longitudinally over 5 feet and transversely over the length of tie plus one-half the depth of fill between the bottom of the tie and the top of the slab, i. e., one-fourth to one slope from end of tie on each side; or 50,000 lbs. distributed over a space five feet by nine feet, or 45 square feet, when allowing two feet of cushion between the bottom of tie and top of slab. This makes 1110 lbs. per sq. ft.

(2) We are using 50 per cent. of live load as impact; this being distributed over same area as live load.

(3) We do not know of any investigation or data other than that by W. W. Colpitts, of the Kansas City, Mexico & Orient Railway.

29.

For ordinary solid floor bridges I have assumed the load to be distributed at 45 degrees beneath each end of the tie, unless the ballast were unusually shallow. Longitudinally I consider the load as distributed three feet minimum due to stiffness of rail. With ordinary depth of ballast I believe that these distributions could be increased to five feet.

In the design of culverts with some fill between the top of structure and the tie I have assumed the material as capable of distributing a live load 15 degrees each side of the tie beyond vertical planes.

In solid floor bridges, and for ordinary depth of ballast, I have used straight 50 per cent. impact, fully believing that the increased dead load absorbed the larger portion of shock.

The only data that I have seen regarding this matter are the writings of W. W. Colpitts and Thos. H. Johnson.

30.

Our practice in designing culverts and reinforced concrete spans is to figure axle loads exactly longitudinally and vertically, and then distribute transversely over 13 feet for each track. We add for impact as per formula $\frac{300}{300 + L}$ times the figured stress and design for total stress, using uniform depth of beam for each length of span. Shear will determine depth of beam for short spans and moment for longer spans.

We make a span of same strength throughout the length of the culvert, and assume that the dead load increases at the rate of 100 lbs. per square foot, per foot of depth of fill, and that effect of live load decreases at same rate.

I do not know of any exhaustive discussion of this subject, but an article on it appeared in the Engineering News of comparatively recent date.

I think the culvert gets its heaviest load when the new embankment is first placed on it, the dead load over the culvert depending largely on the angle of repose of the material. My observation has been that the middle of a culvert under the highest part of the embankment sustains much greater load than that part towards either end, and under high fills it has been our practice to allow for this greater dead load at the center by spreading the footing in the middle third of the culvert over a greater area than that on the outside thirds. We have also used a greater thickness of arch under the middle thirds, but as already stated, this is resorted to only where a high fill justifies a change of plans.

In Prof. Baker's work on "Masonry," the opinion is advanced that the load on culvert is not dependent on height of fill. I cannot agree with this view and I do not think Prof. Baker is now prepared to endorse it.

31.

All our designs for track bridges are based on Cooper's E-50 loading. The actual load of 50,000 lbs. is assumed to be carried by three ties, one-third per tie, which is assumed to give practically a uniform distribution longitudinally of 10,000 lbs. per linear foot; the ties and ballast are assumed to distribute nine feet laterally, giving 1100 lbs. per square foot. We use six-inch ties and a minimum of six inches of ballast under the ties.

For reinforced concrete or embedded I-beam spans of 20 feet or less, the impact addition is 100 per cent.; also for the floor slab of deck or half through plate girder bridges with transverse I-beams, 100 per cent. impact is added.

I cannot give you any information as to investigations or data bearing on this subject as we have not made any such investigations.

32.

(1) This road has no reinforced concrete structures.

(2) In regard to impact, I believe that the depth of fill over the slab is a big factor in determining the impact to be used. I should take the weight of a train as adding about twelve feet to the height of fill over the roof of a culvert. If roof of culvert is over five feet below base of rail I should not add any impact.

Besides textbooks on the subject you may find something in the pamphlets printed by the St. Louis Corrugated Bar Co., Vol. 1, Nos. 3 and 4.

33.

The dead load is taken as acting vertically downward without lateral distribution. The live load moment is taken from the table of E-60 moments and distributed uniformly over a width of ten feet at a depth of two feet below top of rail, this being considered as the minimum

ballast. As the depth increases the width of distribution is increased 12 inches per foot of increase of depth. Impact is taken at 50 per cent. of the live load at two-foot depth and decreased uniformly to zero at 12-foot depth. When these quantities are plotted it develops that the total load per square foot (using an equivalent uniform live load per foot) is about the same at 16- to 20-foot fill as at two-foot fill, being less between these points. Therefore, tables are made for a dead load of 500 lbs. per square foot, the live load as above, and 50 per cent. impact, and the same slab used for all depths of fill. It is assumed that arching of the earth fill begins before the total load per square foot exceeds that given by the above. The slab is made of uniform section for its entire width. The construction consists of I-beams embedded in concrete, the steel figured to take the entire load at 18,000 lbs. per square inch.

Summary of Replies.

	Distribution of Axle Loads.			Impact	Remarks
	Longitudinally	Transversely	Vertically		
1				40% for 2′ ballast; 10 ft. of fill for culverts.........	
2	Uniform...........	10 ft.........	(Vertical)...	Straight 50%......	Floor slabs only.
3	Concentrated......	10 ft.........	(Vertical)...	100%..............	
4	3 ft...............	Tie..........	12″ per ft....	75% for $d < 5$ ft.....	
5	Concentrated......	Entire width of slab......	Equal to increase of load.	25% for fl. slabs; full impact for culverts.........	Add 5 ft. of fill.
6	Uniform; 12,000 lbs. per sq. ft.........	8 ft. at base of rail.........	6″ per ft.....	50%..............	
7	5 ft. for $d \geqq 15'$.....	10 ft.........	6″ per ft.....	50% for $d < 15$ ft....	
8	Concentrated......	10 ft.........	Vertical.....	Full impact, $S \frac{300}{300+L}$	
9	3 ft...............	8 ft..........	Vertical.....	Full impact, $L \times \frac{L}{L+D}$	Design for 3′ fill up to depth at which fill = impact.
10	Uniform; 2,000 lbs. per sq. ft. for culverts............	Uniform.....	(Vertical)...	No impact for culverts.	
11	Concentrated for floor slabs.......	14 ft.........	(Vertical)...	50% of $S \frac{300}{300+L}$	
	Conc. for reinf. parallel with track...	9 to 13 ft.....	(Vertical)...	50% of $L \frac{L}{L+D}$	
	5 ft. for reinf. at angle with track.	9 ft..........	(Vertical)...	50% of $L \frac{L}{L+D}$	
12	24″ for $d \leqq 24''$; Unif. for $d \geqq 6'$........	9 ft	6″ per ft.....	50% for $d \leqq 6'$ to zero for $d \geqq 2 \times$ span.............	
13	5 ft...............	6 ft. for d=2 ft. to 16 ft. for d=10 ft.	3″ per ft. to 6″ per ft.......	50% for $d = 6'$ to zero for $d = 18'$...	

SUMMARY OF REPLIES—Continued.

	Distribution of Axle Loads			Impact	Remarks
	Longitudinally	Transversely	Vertically		
14	Equiv. uniform load	8 ft.	12″ per ft.	Lower unit stresses	Fill not less than 5 ft.
15	4 ft.	8 ft.	24″ per ft.	Full impact, $S\frac{300}{300+L}$	
16			Vertical	100% for $d<5'$ to zero for $d=20'$	
17	Concentrated	12 ft.	(Vertical)	Full impact, $S\frac{300}{300+L}$	
18	Concentrated	8 ft.	24″ per ft.	100%	
19	Uniform	8 ft.	(Vertical)	None.	
20	5 ft.	8 ft.	Vertical	Full impact, $S\frac{300}{300+L}$	
21		Tie	60° from end of tie	Full impact, $\frac{100-S}{3}$	
22	Concentrated	9 ft.	(Vertical)	½ unit stress for L.L.	$\frac{\text{Min.}}{\text{Max.}}$ formula.
23	Concentrated	13 ft.	(Vertical)	Full impact	
24	5 ft.	10 ft.	12″ per ft.	Full impact for min. fill to zero for $d=10'$; $S\frac{300}{300+L}$	
25	5 ft.	10 ft.	12″ per ft.	50% for $d=0$ to 0 for $d=11'$	Arch effect assumed for $d>10'$; uniform slab for all depths.
26	5 ft.	5 ft.	24″ per ft.	Full impact for $d=18''$; $S\frac{300}{300+L}$; to 0 for $d=12'$	
27	Concentrated			$D\times\frac{L}{L+D}$	
28	5 ft.	Tie (9 ft.)	6″ per ft.	50%	
29	3 ft.	Tie (9 ft.)	2x15° for culverts; 24″ per ft. for fl. slabs	50%	
30	Concentrated	13 ft.	Vertical	Full impact, $S\frac{300}{300+L}$	
31	5 ft.	9 ft.	(Vertical)	100%	
32				12 ft. of fill; zero for $d>5$ ft.	
33	Concentrated	10 ft.	12″ per ft.	50% for $d\leqq 2'$ to zero for $d\geqq 12'$	Arch effect assumed for $d>12'$. D.L. 500 lbs. per sq. ft. Uniform slab for all depths.

EXPLANATIONS AND ANALYSIS.

Under the head of "Distribution of axle loads, longitudinally," it will be noticed that twelve use "concentrated" loads and six "uniform" loads. These generally mean the same thing, *i. e.*, a moment taken from the moment table for concentrated loads or an equivalent load deduced from it. Combining these, it appears that 56 per cent. use the moment table, 28 per cent. distribute an axle load over five feet, 16 per cent. over four, and three per cent. over two feet.

Referring to distribution transversely, it should be noted that all of those noted as eight feet, nine feet, ten feet or tie, indicate a uniform distribution for the length of the tie or slightly more, depending on whether the writer considers the distribution at the level of the base of rail or a few inches below the bottom of the tie. Those given as twelve feet, thirteen feet, or fourteen feet, are included with those specifying uniform distribution for the distance between tracks. From this it appears that 71 per cent. distribute over the length of the ties, 23 per cent. over the distance between tracks, and 6 per cent. over a distance of five or six feet.

By "vertical" distribution is meant the lateral distribution at varying depths below the rail. Five each, or 15 per cent., specify vertical, six inches per foot and 12 inches per foot, and four, or 12 per cent., 24 inches per foot. Eleven others have been shown as (vertical), as best indicating the distribution as shown by the context. Combining these, it appears that 44 per cent. prefer a vertical distribution as against 56 per cent. who prefer a lateral distribution varying from 3 inches per foot to 24 inches per foot. It should be noted that 24 inches per foot is a slope of 45 degrees at each end of the tie.

The impact requirements are various and intricate. Some of the salient points may be indicated as follows:

39 per cent. use 50 per cent. impact; 45 per cent. use 50 per cent. or less.

42 per cent. use 100 per cent. impact; 55 per cent. use over 50 per cent.

60 per cent. use constant impact for all depths of fill.

31 per cent. use varying impact for different depths.

51 per cent. use a simple percentage of impact.

45 per cent. use a formula.

Very little information was received in reply to question 3. An article by W. W. Colpitts, formerly Chief Engineer, Kansas City, Mexico & Orient Railway, in the Railway Age, January to April, 1904, sheds no light on the distribution of load; the formulas developed are based on an assumed distribution. Bulletin 28, University of Illinois, gives results of tests showing strength of reinforced concrete slabs. The distribution of load is not investigated. An analysis by Thos. H. Johnson, Consulting Engineer, in the Proceedings of the American Railway Engineering Association, in Vol. 7, page 102, of some experiments on the distribution of load through ballast, is of some value. A description of the experiment referred to follows the analysis.

SERVICE TESTS OF CROSS-TIES

By P. R. Hicks

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The records embodied in the accompanying tables were compiled as a continuation of the report published in the 1917 Proceedings of the American Railway Engineering Association. The report which appeared in the 1917 Proceedings included all records of 1916 inspections upon which information was available at the time of printing. The tables included in this report cover treated and untreated ties which either had been in service for a period of at least eight years or records where at least 25 per cent. of the ties had been removed.

In certain test tracks, if 25 per cent. of one species of ties had been removed, the other species are listed for comparison irrespective of the number removed or the period of service. However, no rcords are included unless inspections were reported in 1917.

The accompanying tables comprise about 350 service test records on twenty-eight different species of ties, including thirty completed records, submitted by twenty-two railroads.

TABLE I—SERVICE TEST RECORDS OF CROSS-TIES—1917.

RAILROAD	CREOSOTE				Untreated	Zinc Chloride Burnett	ZINC CREOSOTE		Zinc Tannin Wellhouse	Others	Species of Wood	Total Numbers
	Full Cell	Open Tank	Lowry	Rueping			Card	Not Stated				
Atlantic Coast Line	1				2						2	3
Atchison, Topeka & Santa Fe				16		4						20
Chicago, Burlington & Quincy	1				2	4	7			4	10	18
Chicago, Milwaukee & St. Paul	4			4	8	14	6	4		5	10	45
Chicago & Northwestern		1			12	6			56		3	75
Chicago, Rock Island & Pacific					2				1		2	3
Chicago & Western Indiana									5		1	5
Galveston, Harrisburg & San Antonio	19	1			7	12		9		3	7	51
Great Northern	2				9	21					5	32
Georgia	2										1	2
Louisville & Nashville	1										1	1
Missouri Pacific					1	1					2	2
Northern Pacific			5		26	4				1	8	36
Norfolk Southern	2				8				6		3	16
New York, New Haven & Hartford				1						3	2	4
Oregon-Washington Railroad & Navigation Co.	1				2	3				1	1	7
Pennsylvania	1			1	2						3	4
Pittsburgh, Shawmut & Northern					3						2	3
Southern Pacific						5				1	1	6
St. Louis-San Francisco	1			3						4	2	8
Tennessee Coal, Iron and Railroad					2					6	4	8
Washington Terminal					1						1	1
Total	35	2	5	25	87	74	13	13	68	28	28	350

Acknowledgment is made to the railroad officials and others who furnished the information, data, and records upon which this report is based.

Table I summarizes the source of all records which appear in detail in the main tables. Several service test records were submitted which are not included in this report because the ties had not been in place long enough to show interesting results. There are, it is believed, many other railroad companies who have authentic tie durability records, and it is hoped that Association members and others will notify the writer of existing test ties for future reports.

Table II, which is self-explanatory, gives a brief summary of thirty records of ties, all of which were reported removed in the 1917 inspection reports. Other completed records have been published in part in several of the annual Proceedings of the American Wood Preservers' Association and the American Railway Engineering Association.

TABLE II—SUMMARY OF COMPLETED RECORD.

Species	No. of Ties	Date Set	Date last Inspection	Preservative	Process	Railroad	Ave. Life (Years)
Cedar No. White	2001	1898	1917	Untreated		C.R.I.& P.	17.2
Fir, Douglas (Coast)	18 mi.	1903	1917	Zinc Chloride	Burnett	S. P.	6
Fir, Douglas (Coast)	20. mi.	1903	1917	Zinc Chloride	Burnett	S. P.	12
Fir, Douglas (Coast)	3. mi.	1903	1917	Zinc Chloride	Burnett	S. P.	6
Fir, Douglas (Coast)	6. mi.	1903	1917	Zinc Chloride	Burnett	S. P.	7
Gum, Red	44	1905	1917	Zinc Chloride	Burnett	G.H.& S.A.	6.7
Gum, Red	49	1905	1917	Zinc Chloride	Burnett	G.H.& S.A.	7.3
Gum, Red	32	1905	1917	Zinc Chloride	Burnett	G.H.& S.A.	7.3
Gum, Red	34	1905	1917	Zinc Chloride	Burnett	G.H.& S.A.	7.0
Gum, Red	40	1905	1917	Zinc Chloride	Burnett	G.H.& S.A.	7.0
Gum, Tupelo	48	1909	1917	Untreated		C. B. & Q.	4.0
Gum, Tupelo	88	1909	1917	Untreated		C. B. & Q.	2.9
Gum, Tupelo	30	1905	1917	Untreated		G.H.& S.A.	8.0
Gum, Tupelo	37	1905	1917	Untreated		G.H.& S.A.	7.0
Gum, Tupelo	46	1905	1917	Untreated		G.H.& S.A.	7.0
Gum, Tupelo	33	1905	1917	Untreated		G.H.& S.A.	7.9
Gum, Tupelo	30	1905	1917	Untreated		G.H.& S.A.	7.0
Juniper	920	1897	1917	Untreated		N. & S.	13.2
Larch, Western	551	1907	1917	Untreated		N. P.	7.3
Larch, Western	568	1907	1917	Untreated		N. P.	7.4
Pine, Longleaf	2100	1899	1917	Untreated		C.M.& St.P.	12.1
Pine, Longleaf	434	1905	1917	Untreated		G.H.& S.A.	4.7
Pine, Sap	333	1905	1917	Zinc Chloride	Burnett	G.H.& S.A.	5.6
Pine, Sap	334	1905	1916	Zinc Chloride	Burnett	G.H.& S.A.	5.5
Pine, So. Yellow	125	1897	1917	Zinc Tannin	Wellhouse	N. & S.	15
Pine, So. Yellow	100	1897	1917	Zinc Tannin	Wellhouse	N. & S.	16
Pine, So. Yellow	2916	1908	1917	Zinc Chloride	Burnett	G. N.	8.4
Tamarack	20	1907	1917	Untreated		C. & N. W.	6.6
Tamarack		1907	1917	Untreated		C.& N.W.	6.5
Tamarack	2894	1908	1917	Untreated		G. N.	7

The following statement, submitted by Mr. J. H. Waterman, of the Chicago, Burlington & Quincy Railroad, is of general interest, as it summarizes the various treatments by species and is an average of the conditions on twenty divisions of this railroad in the states of Wisconsin, Illinois, Missouri, Iowa, Nebraska, Colorado, South Dakota, and Wyoming. The ties were set in the fall of 1909 and in the spring of 1910:

TIES PLACED IN EXPERIMENTAL TRACKS, C. B. & Q. RAILROAD, 1909-1910.

Process	*Total Placed*	*Total Removed to Jan., 1918*	*Per Cent. Removed Account Decay*	*Per Cent. Removed to Jan., 1918. Other Causes*
		ASH.		
Straight Creosote.	35	....	....	....
Card Process	388	19	.5	4.3
Burnett	31	....	....	....
Untreated	116	107	90.5	1.7
		BIRCH.		
Straight Creosote.	133	....	....	....
Card Process	1,075	45	.3	3.9
Burnett	103	5	1.9	3.0
Untreated	217	214	98.6	....
		CYPRESS.		
Straight Creosote.	54	....	....	....
Card Process	662	18	.2	2.6
Burnett	55	....	....	....
Untreated	225	132	56.3	2.3
		COTTONWOOD.		
Straight Creosote.	133	5	....	3.8
Card Process	456	27	....	4.0
Burnett	...	....	....	....
Untreated	86	86	96.0	4.0
		ELM.		
Straight Creosote.	328	11	1.0	2.2
Card Process	957	18	.5	1.1
Burnett	297	11	.7	3.0
Untreated	190	167	82.0	6.0
		SOFT MAPLE.		
Straight Creosote.	201	11	1.0	4.5
Card Process	731	48	.9	5.8
Burnett	182	15	1.5	6.7
Untreated	125	122	98.0	....
		RED GUM.		
Straight Creosote.	137	8	....	5.8
Card Process	661	26	1.1	3.0
Burnett	119	30	18.3	6.7
Untreated	151	148	96.6	1.0
		HEMLOCK.		
Straight Creosote.	235	4	....	1.7
Card Process	1,298	51	.1	3.9
Burnett	213	6	1.4	1.4
Untreated	191	180	93.6	.5

Process	*Total Placed*	*Total Removed to Jan., 1918*	*Per Cent. Removed Account Decay*	*Per Cent. Removed to Jan., 1918. Other Causes*
		BEECH		
Straight Creosote.	484	2	....	.4
Card Process	1,226	36	.09	2.8
Burnett	315	28	1.9	6.6
Untreated	207	188	88.8	2.0
		HICKORY.		
Straight Creosote.	25	1	4.0	....
Card Process	290	23	1.1	6.4
Burnett	24	....	....	....
Untreated	110	95	82.4	4.0
		POPLAR.		
Straight Creosote.	80	1	....	1.2
Card Process	645	54	1.0	7.4
Burnett	80	2	1.5	1.5
Untreated	125	112	86.6	3.0
		HARD MAPLE.		
Straight Creosote.	116	....	....	....
Card Process	831	24	.5	2.5
Burnett	65	1	....	2.0
Untreated	121	113	92.0	1.0
		PIN OAK.		
Straight Creosote.	321	....	....	....
Card Process	833	11	....	1.3
Burnett	68	....	....	....
Untreated	125	106	84.0	.8
		LOBLOLLY OR SAP PINE.		
Straight Creosote.	205	7	.5	2.9
Card Process	1,344	120	4.0	5.0
Burnett	200	30	8.0	7.0
Untreated	249	216	83.0	3.7
		CHESTNUT.		
Straight Creosote.	...	....	....	....
Card Process	253	103	2.0	39.0
Burnett	...	....	....	....
Untreated	258	112	10.7	32.0
		RED OAK.		
Straight Creosote.	284	1	....	.4
Card Process	1,280	26	.1	1.9
Burnett	272	18	1.1	5.5
Untreated	209	192	88.9	3.0
		SYCAMORE.		
Straight Creosote.	90	1	1.0	....
Card Process	521	34	2.7	3.9
Burnett	90	4	1.0	3.0
Untreated	130	129	97.0	2.0

Process	Total Placed	Total Removed to Jan., 1918	Per Cent. Removed Account Decay	Per Cent. Removed to Jan., 1918. Other Causes
TAMARACK				
Straight Creosote.	212	7	....	3.0
Card Process	1,309	26	.2	1.8
Burnett	214	5	....	2.0
Untreated	175	164	92.8	1.0
TUPELO GUM.				
Straight Creosote.	151	5	....	3.3
Card Process	671	12	....	1.7
Burnett	117	7	2.0	3.9
Untreated	136	136	100.0	....
WHITE OAK.				
Straight Creosote.	40	....	....	....
Card Process	386	9	....	2.0
Burnett	43	....	....	....
Untreated	124	21	16.9	....

A general summary, regardless of species, follows:

SUMMARY.

Process	Total Placed	Total Removed to Jan., 1918	Per Cent. Removed Account Decay	Per Cent. Removed to Jan., 1918. Other Causes
Straight Creosote	3,264	64	.3	1.6
Card Process ...	15,817	730	.6	3.9
Burnett	2,488	162	2.7	3.8
Untreated	3,270	2,740	82.2	3.4

DESCRIPTION OF MATERIAL								SERVICE			
Dimensions	Form	Preparation	No. of Ties in Test	Where Grown	Spacing in Track	Average Absorption Lbs. per Tie	Average Absorption Lbs. per Cu.ft.	Date placed	Name of R. R.	Location	Curve or Tangent
ASH CREOSOTE — LOWRY											
7x9x8...	Hewed	Seasoned, not bored for spikes	44	Minn......	19 to rail......	......	6.5	1908	N. P..........	Sumner, Wash.	Tangent
BIRCH CREOSOTE — LOWRY											
7x9x8 ..	Hewed	Seasoned, not bored for spikes	49	Minn......	19 to rail......	22.8	6.5	1908	N. P..........	Sumner, Wash	Tangent.
CATALPA — UNTREATED											
7x8x8½..	Hewed	Bored for spikes...	495	Ohio......	16 to 33′ rail....	......	......	1909	Pa.Sys.West...	St.Paris,Ohio.	2° Tang.
7x8x8½..	Hewed	Bored for spikes...	122	Ohio......	17 to 33′ rail....	......	......	1909	Pa.Sys.West...	Urbana, Ohio..	Tangent.
CEDAR NORTHERN WHITE — UNTREATED											
7x7x8...	Pole...	....	500	Nor.Mich..	17 to rail......	......	......	1902	C. M. & St. P..	Lyndon, Wis...	Tangent
6x8x8...	Pole...	....	177	Nor.Mich..	22 to rail......	......	......	1911	C. M. & St. P..	Monroe, Wis...	Tangent
6x8x8...	Hewed	....	11516	Mich......	....	......	......	1900	C. R. I. & P....	Sibley, Iowa...	Tangent
6x8x8...	Hewed	Seasoned..	2001	....	....	......	......	1898	C. R. I. & P....	Vinton, Iowa...	Tangent
CHESTNUT ZINC CHLORIDE — BURNETT											
6x6x8...	....	Seasoned..	23	....	18 to rail......	......	.5	1911	C. M. & St. P..	Hartford, Wis..	Tangent.
CYPRESS CRUDE OIL											
....	....	....	3	....	....	......	......	1911	C. B. & Q.....	Baders, Ill......	...

CONDITIONS							RESULTS						
% of Grade	Tie Plates		Kind of Spikes	Wt. of Rail, Lbs.	Ballast	Traffic Tons per Year	Date Inspected.	Time of Service, Years	% Removed	Cause of Removal		Present Condition	Av'ge Life, Yrs
	Kind	Size								Decay %	Wear %		
....	Flat, 6"	x8½"x$\frac{9}{16}$"	Cut...........	90	Gravel....	Heavy....	1917	9	0	....	....	Good..	......
....	Flat, 6"	x8½"x$\frac{9}{16}$"	Cut...........	90	Gravel....	Heavy....	1917	9	0	....	....	Good..	....
1.1 Down grade......	Flat, 7"	x10"....	Screw.........	100	Gravel....	11,000,000	1917	8	70	Wear an	d decay	Poor..	....
.7 Down grade......	Goldie	.7"x9"...	Screw, replaced by cut 1916.	85	Gravel....	11,000,000	1917	8	47	Wear an	d decay	Poor...	....
1............	A. C. & 4½"x7	M. F... ½"......	Cut...........	85	Gravel....	Heavy....	1917	15	69	Decay, and r	wear ail cut..	Badly rail cut.	......
....	None.	....	Cut...........	60	Cinders....	Heavy....	1917	6	29	Derail brok	ties en......	Good..	......
....	None.	....	Cut...........	60	Gravel and Cinders..	Light.....	1917	17	21.2	Variou	s.......	Fair...	......
....	5"x7½"x	½"......	Cut..........	80	Gravel....	13,000 per day.....	1917	19	100	Variou	s.......	....	17.2
Level........	Flat St	eel......	65% Cut 35% Screw.....	90	Gravel....	Heavy....	1917	6	0	....	....	74% Good.	....
....	None e unde	xcept r Joints.	Cut...........	75	Gravel....	....	1917	6	33	Decay.	....	....	.....

DESCRIPTION OF MATERIAL								SERVICE			
Dimensions	Form	Preparation	No. of Ties in Test	Where Grown	Spacing in Track	Average Absorption Lbs. per Tie	Average Absorption Lbs. per Cu.ft.	Date placed	Name of R. R.	Location	Curve or Tangent
CYPRESS — UNTREATED											
7x9x8...	....	....	3637	....	....	......	......	1909	G. H. & S. A..	Bay View and San Leon, Texas.......	....
7x9x8...	....	....	2290	....	....	......	......	1909	G. H. & S. A..	Bay View and San Leon, Texas.......	....
7x9x9...	....	....	6675	....	....	......	......	1910	G. H. & S. A..	Lafayette and Scott.......	....
7x8x9...	....	....	500	....	....	......	......	1905	G. H. & S. A..	Bay View and San Leon, Texas.......	....
7x8x9...	....	....	500	....	....	......	......	1905	G. H. & S. A..	Bay View and San Leon, Texas.......	....
ELM CREOSOTE — LOWRY											
7x9x8...	Hewed	Seasoned, 6 mos...	53	Minn......	19 to rail......	22.8	6.5	1908	N. P..........	Sumner, Wash.	Tangent.
ELM — WHITE CRUDE OIL											
....	....	....	2	....	....	......	......	1911	C. B. & Q.....	Baders, Ill.....	....
ELM — WHITE ZINC CREOSOTE — CARD.											
....	....	....	195	....	....	......	.5# zn. 3# creo	1908	C. B. & Q.....	Lines East.....	....
FIR — DOUGLAS — COAST CARBOLINEUM											
7x9x8...	Sawed.	Sun dried 90 days..	300	Ore.or Wash	18 to rail.......	......	1.2	1908	O.W.Ry.&N.Co	Dodson, Ore.	Tangent.
(CREOSOTE) FIR — DOUGLAS — COAST											
7x9x8...	Sawed.	Unseasoned	1000	Ore.orWash	18 to rail.......	......	8	1908	O.W.Ry.&N.Co	Dodson, Ore...	1° partly Tangent
....	Square Sawed	....	3453	Coast.....	....	......	12	1911	G. N..........	Butte Div ...	Tang.70%, Curve30%
....	Hewed	....	2938	Coast.....	....	......	12	1911	G. N..........	Butte Div.....	Tang.70%, Curve30%

CONDITIONS							RESULTS						
% of Grade	Tie Plates		Kind of Spikes	Wt. of Rail, Lbs.	Ballast	Traffic Tons per Year	Date Inspected.	Time of Service, Years	% Removed.	Cause of Removal		Present Condition	Av'ge Life, Yrs.
	Kind	Size								Decay %	Wear %		
....	Clark..	....	Screw........	80	Gravel....	....	1917	8	5.9	....	....	Good..	......
....	Clark..	....	Screw........	80	Gravel....	....	1917	8	7 1	....	....	Good..	......
....	Clark..	....	Screw........	80	Gravel....	....	1917	7½	0	....	....	Good..	......
.. ..	None..	....	....	......	Gravel....	....	1917	12	100	....	....	....	......
.. ..	Glendo	n........	....	......	Gravel....	....	1917	12	100	....	....	....	......
....	Flat 6x8½x	5/16......	Cut...........	90	Gravel....	Heavy....	1917	9	0	....	....	Good..	......
....	None e under	xcept r joints.	Cut..........	75	Gravel....	....	1917	6	50	Rail...	Cut...	....	......
....	On cur	ves.....	Cut...........	90	Gravel....	....	1917	8	7.2	Broken Split	and	....	......
....	....	8"x8"x½"	Cut...........	75	Gravel....	Heavy....	1917	9	32	Decay	and split	Fair...	......
.35...........	....	8"x8½"..	Cut...........	C. S. Sec.75	Gravel replaced with crushedrock	6,000,000	1918	9	.3	Decay.	....	Good..	......
....	Goldie	6½"x8½".	⅝"x6"..........	G. N. 90	Gravel....	....	1917	6⅓	38	Crushi checki	ng and ng......	Very p	oor
....	Goldie	6½"x8½".	⅝"x6"..........	G. N. 90	Gravel....	....	1917	6⅓	69	Crushi checki	ng and ng......	Very p	oor

DESCRIPTION OF MATERIAL								SERVICE			
Dimensions	Form	Preparation	No. of Ties in Test	Where Grown	Spacing in Track	Average Absorption Lbs. per Tie	Average Absorption Lbs. per Cu.ft.	Date placed	Name of R. R	Location	Curve or Tangent
FIR — DOUGLAS — COAST CREOSOTE AND CRUDE OIL											
7x9x8...	....	Seasoned 8 months	156	Wash......	19 to rail.......	42	12	1911	N. P..........	Seattle, Wash..	Tangent.
FIR — DOUGLAS — COAST UNTREATED											
7x9x8...	Sawed.	Unseasoned	1007	Oregon....	18 to rail.......	......	......	1908	O.W.Ry.&N.Co	Dodson, Ore...	Tangent
7x9x8...	Sawed.	Sun dried 90 days..	1006	Oregon or Wash.Coast	18 to rail.......	......	......	1908	O.W.Ry.&N.Co	Dodson, Ore...	Tangent
FIR — DOUGLAS — COAST ZINC CHLORIDE — BURNETT											
7x9x8...	Sawed.	Sun dried 90 days..	977	Oregon or Wash.Coast	18 to rail.......	......	0.25	1908	O.W.Ry.&N.Co	Dodson, Ore...	Tangent.
7x9x8...	Sawed.	Unseasoned	975	Oregon or Wash.Coast	18 to rail.......	.....	0.25	1908	O.W.Ry.&N.Co	Dodson, Ore...	Tangent.
7x9x8...	Hewed	Sun dried 6 months	1969	Oregon or Wash.Coast	18 to rail.......	......	0.25	1908	O.W.Ry.&N.Co	Dodson, Ore..	Tangent
7x9.....	Hewed	Seasoned..	18 miles	Oregon or Wash.Coast	16 to 30′ rail...	......	......	1903	S. P..........	Utah..........	....
7x9.....	....	....	20 miles	....	16 to 30′ rail...	......	......	1903	S. P..........	Beppo, Utah...	....
7x9.....	Sawed.	Seasoned..	3 miles	....	16 to 30′ rail...	......	......	1903	S. P..........	Ogden, Utah..	....
7x9.....	Sawed.	Seasoned..	46 miles	....	....	......	......	1903	S. P..........	Hogup, Utah..	....
7x9.....	Sawed.	Seasoned..	6 miles.	....	16 to 30′ rail...	......	......	1903	S. P..........	Loy, Utah....	....
FIR — DOUGLAS — COAST ZINC CHLORIDE AND CRUDE OIL											
7x8x8...	Sawed.	Seasoned, not bored for spikes	93	Oregon....	23″ centers.....	.782 zn. cl. 11.95 cr. oil	0.25 zn. cl 3.84 cr. oil	1906	S. P..........	Tracy, Cal....	Tangent
7x8x8...	Sawed.	Unseasoned not bored for spikes	140	Ore.andCal.	18 to rail.......	2508 zn. cl. 7.25 cr.oil	.0718 zn. cl 2.02 cr.oil	1906	S. P..........	Arbuckle, Cal .	Tangent

CONDITIONS							RESULTS						
% of Grade	Tie Plates		Kind of Spikes	Wt. of Rail, Lbs.	Ballast	Traffic Tons per Year	Date Inspected	Time of Service, Years	% Removed	Cause of Removal		Present Condition	Av'ge Life, Yrs.
	Kind	Size								Decay %	Wear %		
....	Flat 6x	8½......	Cut............	...90	Gravel....	Heavy....	1917	6	55	....	....	Good..	......
....	8"x8½".	....	Cut............	C. S. Sec.75	Gravel....	6,000,000	1917	9	58.2	Decay	and spli	tting...	......
....	8"x8½".	....	Cut............	C. S. Sec.75	Gravel....	6,000,000	1917	9	60.4	Checki Deca	ng and y.......	Fair...	......
....	8"x8½".	....	Cut............	C. S. Sec.75	Gravel....	6,000,000	1917	9	5.7	Decay, and c	split hecked.	Fairly	good
....	8"x8½".	....	Cut............	C. S. Sec.75	Gravel....	6,000,000	1917	9	6.7	Split a chec	nd ked.....	Fair...	......
....	8"x8½".	....	Cut............	C. S. Sec.75	Gravel....	6,000,000	1917	9	7.0	....	....	....	......
....	Yes...	....	Cut............	80	Gravel....	....	1917	14	100	Decay chec	and ked.....	.......A	bout 6
....	Yes...	....	Cut............	80	Gravel....	....	1917	14	100	Decay.	....	.....Ab	out 12
....	Wolhau	pter....	Cut............	80	Gravel....	....	1917	14	100	Decay.	....	.......A	bout 6
....	Yes...	....	Cut............	80	Gravel....	....	1917	14	70	Breaki Deca	ng and y.......	Good..	......
....	Yes...	....	Cut............	80	Gravel....	....	1917	14	100	Checki Deca	ng and y.......	....	7
Level........	Ribbed	4½"x8"..	Cut............	80	Dirt and Gravel..	Very heavy	1917	11	30.1	Change and r	in track ail cut..	Good..	......
Level........	Ribbed chgd.	1915 to Sacto	Cut............	90	Gravel...	Very heavy	1916	10	2.8	Rail cu	t.......	....	......

DESCRIPTION OF MATERIAL								SERVICE			
Dimensions	Form	Preparation	No. of Ties in Test	Where Grown	Spacing in Track	Average Absorption Lbs. per Tie	Average Absorption Lbs. per Cu.ft.	Date placed	Name of R. R.	Location	Curve or Tangent
FIR — DOUGLAS — MOUNTAIN UNTREATED											
7x9x8	Hewed	Unseasoned	95	Mountains	18 to rail			1907	N. P	Plains, Mont	Tangent
7x9x8	Hewed	Unseasoned	94	Mountains	18 to rail			1907	N. P	Plains, Mont	Tangent
7x9x8	Hewed	Unseasoned	108	Mountains	18 to rail			1907	N. P	Plains, Mont	Tangent
7x9x8	Hewed	Unseasoned	91	Mountains	18 to rail			1907	N. P	Plains, Mont	Tangent
7x9x8	Hewed	Unseasoned	90	Mountains	18 to rail			1907	N. P	Plains, Mont	Tangent
7x9x8	Hewed	Seasoned	32	Mountains	18 to rail			1907	N. P	Plains, Mont	Tangent
7x9x8	Hewed	Seasoned	90	Mountains	18 to rail			1907	N. P	Plains, Mont	Tangent
7x9x8	Hewed	Seasoned	90	Mountains	18 to rail			1907	N. P	Plains, Mont	Tangent
7x9x8	Hewed	Seasoned	90	Mountains	18 to rail			1907	N. P	Plains, Mont	Tangent
7x9x8	Hewed	Seasoned	90	Mountains	18 to rail			1907	N. P	Plains, Mont	Tangent
7x9x8	Hewed	Seasoned	90	Mountains	18 to rail			1907	N. P	Plains, Mont	Tangent
7x9x8	Hewed	Seasoned	89	Mountains	18 to rail			1907	N. P	Plains, Mont	Tangent
7x9x8	Hewed	Unseasoned	92	Mountains	18 to rail			1907	N. P	Plains, Mont	Tangent
	Slabbed		1,340	Mountains				1911	G. N	Butte Div	T. 70% C. 30%
	Sawed	Triangular	856	Mountains				1911	G. N	Butte Div	
FIR — DOUGLAS — MOUNTAIN ZINC CHLORIDE — BURNETT											
			3120				0.5	1906	C. B. & Q	Kane, Wyo	
7x9x8	Sawed	Partly Seasoned	107	Mountains	18 to rail		0.651	1907	N. P	Plains, Mont	Tangent
7x9x8	Sawed	Partly Seasoned	90	Mountains	18 to rail		0.651	1907	N. P	Plains, Mont	Tangent
	Sawed Triangular		1635	Mountains			0.5	1911	G. N	Butte Div	T. 70% C. 30%
	Sawed Trianglar		1980	Mountains			0.75	1911	G. N	Butte Div	T. 70% C. 30%
	Sawed Square		881	Mountains			0.5	1911	G. N	Butte Div	T. 70% C. 30%
	Sawed Square		819	Mountains			0.75	1911	G. N	Butte Div	T. 70% C. 30%
	Slabbed		1286	Mountains			0.5	1911	G. N	Butte Div	T. 70% C. 30%
	Slabbed		1215	Mountains			0.75	1911	G. N	Butte Div	T. 70% C. 30%
GUM — RED CREOSOTE — FULL CELL											
6x8x8	Sawed		33			38.45	14 45	1905	G. H. & S. A	Bay View and San Leon, Tex.	
6x8x8	Sawed		29			38.45	14.45	1905	G. H. & S. A	Bay View and San Leon, Tex.	
6x8x8	Sawed		26			38.45	14.45	1905	G. H. & S. A	Bay View and San Leon, Tex.	
6x8x8	Sawed		45			33.31	12.52	1905	G. H. & S. A	Bay View and San Leon, Tex.	
6x8x8	Sawed		39			33.31	12.52	1905	G. H. & S. A	Bay View and San Leon, Tex.	
6x8x8	Sawed		28			33.31	12.52	1905	G. H. & S. A	Bay View and San Leon, Tex.	

CONDITIONS							RESULTS						
% of Grade	Tie Plates		Kind of Spikes	Wt. of Rail, Lbs.	Ballast	Traffic Tons per Year	Date Inspected	Time of Service, Years	% Removed	Cause of Removal		Present Condition	Av'ge Life, Yrs.
	Kind	Size								Decay %	Wear %		
017	Wolhau Seller	pter and s	Screw and cut	75 and 85	Gravel	8,270,506	1916	9.3	100				7.6
.017	Wolhau	pter	Cut	85	Gravel	8,270,506	1915	8.3	100				7.6
.017	Sellers.		Screw and cut	85	Gravel	8,270,506	1916	9.3	100				7.6
.017	Sellers.		Cut	85	Gravel	8,270,506	1915	8.3	100				7.6
.017	Sellers.		Screw	85	Gravel	8,270,506	1915	8.3	100				7.7
.017	Oakwo Wolh	od and aupter	Screw and cut	72	Gravel	8,270,506	1916	9.3	100				.6
.017	Wolhau	pter	Cut	85	Gravel	8,270,506	1916	9.3	100				7.7
.017	Sellers.		Cut	85	Gravel	8,270,506	1916	9.3	100				7.7
.017	Sellers.		Cut	85	Gravel	8,270,506	1916	9.3	100				7.7
.017	Sellers.		Screw and cut	85	Gravel	8,270,506	1916	9.3	100				7.7
.017	Sellers.		Screw	85	Gravel	8,270,506	1916	9.3	100				7.7
.017	N.P.21		Cut	85	Gravel	8,270,506	1916	9.3	100				7.7
.017	Sellers.		Cut	85	Gravel	8,270,506	1916	9.3	100				
	Goldie	6½x8½	Cut	90	Gravel		1917	6⅓	32	Decay.		Very poor.	
	Goldie	6½x8½	Cut	90	Gravel		1917	6⅓	2				
	None.		Cut	65	Gravel		1917	11	.0075			Good.	
017	Sellers		Screw and cut.	85	Gravel	8,270,506	1916	9.3	7.5	Split		73% Good.	
017	Sellers		Screw	85	Gravel	8,270,506	1916	9.3	6.7	Split		70% Good.	
	Goldie J.G. 58	6½x8½	Cut	90	Gravel		1917	6⅓	0			Good.	
	Goldie J.G. 58	6½x8½	Cut	90	Gravel		1917	6⅓	.1	Decay.		Good	
	Goldie J.G. 58	6½x8½	Cut	90	Gravel		1917	6⅓	1	Decay.		Good.	
	Goldie J.G. 58	6½x8½	Cut	90	Gravel		1917	6⅓	0			Good.	
	Goldie J.G. 58	6½x8½	Cut	90	Gravel		1917	6⅓	0			Good.	
	Goldie J.G. 58	6½x8½	Cut	90	Gravel		1917	6⅓	0			Good.	
	None.						1917	12	31.8				
	Glendon						1917	12	17.2				
			Screw				1917	12	7.7				
	None.						1917	12	72.1				
	Glendon						1917	12	33.3				
			Screw				1917	12	47 8				

Description of Material								Service			
Dimensions	Form	Preparation	No. of Ties in Test	Where Grown	Spacing in Track	Average Absorption Lbs. per Tie	Average Absorption Lbs. per Cu.ft.	Date placed	Name of R. R.	Location	Curve or Tangent
GUM — RED CREOSOTE — RUEPING											
6x8x8...	Sawed	Seasoned 2 years..	321	....	....	9.8	......	1906	St. L. & S. F..	St. Clair, Mo	Tangent
....	Sawed	Air Seasoned	390	....	....	......	5.0	1907	A. T. & S. F...	Hutchinson, Kan.........	....
....	Sawed	Air....... Seasoned	230	....	....	......	5.0	1907	A. T. & S. F...	Hutchinson, Kan.........	....
....	Sawed	Air Seasoned	262	....	....	......	5.0	1907	A. T. & S. F...	Plevna, Kan...	....
GUM — RED DIAMOND WOOD PRESERVER											
7x9x8...	Hewed	....	500	....	....	.4 gal.	0.11 gal.	1907	G H. & S. A..	Ft. Hancock and Iser, Tex	
7x9x8...	Hewed	....	500	....	....	.73 gal.	0.21 gal.	1907	G. H. & S. A..	Ft. Hancock and Iser, Tex	....
7x9x8...	Hewed	... .	500	....	....	.52 gal.	0.15 gal.	1907	G. H. & S. A..	Ft. Hancock and Iser, Tex	....
GUM — RED ZINC CHLORIDE — BURNETT											
6x8x8...	Sawed	....	44	....	....	.7285	.2738	1905	G. H. & S. A..	Bay View and San Leon, Tex........	...
6x8x8...	Sawed	....	49	....	....	.8107	.3047	1905	G. H. & S. A..	Bay View and San Leon, Tex........	....
6x8x8...	Sawed	....	32	....	....	.8107	.3047	1905	G. H. & S. A..	Bay View and San Leon, Tex........	....
6x8x8...	Sawed	....	34	....	....	.8107	.3047	1905	G. H. & S. A..	Bay View and San Leon, Tex.	....
6x8x8...	Sawed	....	40	....	....	.7285	.2738	1905	G. H. & S. A..	Bay View and San Leon, Tex........	....
GUM — RED ZINC CREOSOTE — CARD											
....	....	....	194	....	....	......	.5 zn. cl. 3/creo	1908	C. B. & Q.....	Lines East....	....

CONDITIONS							RESULTS						
% of Grade	Tie Plates		Kind of Spikes	Wt. of Rail, Lbs.	Ballast	Traffic Tons per Year	Date Inspected.	Time of Service, Years	% Removed.	Cause of Removal		Present Condition	Av'ge Life, Yrs.
	Kind	Size								Decay %	Wear %		
....	Since 1914 cut 8¾"x6½"		....	75to90	Gravel, Cinders since 1914	8,300,000	1917	11	14.3	7.8	6.5	Good..	......
....	7½"x9"	....	Cut...........	90	Rock......	....	1917	10	2.8	1.3	1.5	....	......
....	7½"x9"	....	Cut...........	85	Cinders....	....	1917	10	0	....	....	....	......
....	7½"x9"	....	Cut...........	90	Rock......	....	1917	10	1.5	....	1.5	....	......
....	Glendon.......		Cut...........	......	Slag.......	....	1917	10½	52.8	....	....	....	......
....	Glendon.......		Cut...........	......	Slag.......	....	1917	10	17.0	....	....	....	......
....	Glendon.......		Cut...........	......	Slag.......	....	1917	10½	3.4	....	....	....	......
....	None..	....	....	......	....	....	1917	12	100	....	....	....	6.7
....	None..	....	....	......	....	....	1917	12	100	....	....	....	7.3
....	....	....	Screw........	......	....	....	1917	12	100	....	....	....	7.3
....	Glendon.......		....	......	....	....	1917	12	100	....	....	....	7.0
....	....	....	Screw........	......	....	....	1917	12	100	....	....	....	7 0
....	Yes...	....	Cut...........	90	Gravel....	....	1917	9	35	Rail cut.......		....	......

DESCRIPTION OF MATERIAL								SERVICE			
Dimensions	Form	Preparation	No. of Ties in Test	Where Grown	Spacing in Track	Average Absorption Lbs. per Tie	Average Absorption Lbs. per Cu.ft.	Date placed	Name of R. R.	Location	Curve or Tangent
GUM — RED ZINC — CREOSOTE											
6x8x8...	Sawed	Seasoned 1 yr. after Treatment	17	....	....	1.01 zn. cl. 17.7 creo.	0.27 zn. cl. 4.49 creo.	1905	G. H. & S. A..	Bay View and San Leon, Tex........	....
6x8x8	Sawed	Seasoned 1 yr. after Treatment	16	....	....	1.01 zn. cl. 17.7 creo.	0.27 zn. cl. 4.49 creo.	1905	G. H. & S. A..	Bay View and San Leon, Tex........	....
6x8x8...	Sawed	Seasoned 1 yr. after Treatment	12	....	....	1.01 zn. cl. 17.7 creo.	0.27 zn. cl. 4.99 creo.	1905	G. H. & S. A..	Bay View and San Leon, Tex........	....
GUM ZINC TANNIN — WELLHOUSE											
....	Hewed	Seasoned 6 mos...	25	....	....	....	....	1897	N. S.........	Norfolk Div...	2°
....	Hewed	Seasoned 6 mos...	100	....	....	....	4.22	1897	N. S.........	Norfolk Div...	Tangent.
....	Sawed	Seasoned 6 mos...	100	....	....	....	1.36	1897	N. S.........	Norfolk Div...	Tangent
GUM — TUPELO CREOSOTE — FULL CELL											
6x8x8...	Sawed	Seasoned 1 yr. after Treatment	35	....	....	35.14	13.21	1905	G. H. & S. A..	Bay View and San Leon, Tex........	....
6x8x8...	Sawed	Seasoned 1 yr. after Treatment	30	....	....	35.14	13.21	1905	G. H. & S. A..	Bay View and San Leon, Tex........	....
6x8x8...	Sawed	Seasoned 1 yr. after Treatment	23	....	....	35.14	13.21	1905	G. H. & S. A..	Bay View and San Leon, Tex........	....
6x8x8...	Sawed	Seasoned 1 yr. after Treatment	44	....	....	29.82	11.21	1905	G. H. & S. A..	Bay View and San Leon, Tex........	....
6x8x8...	Sawed	Seasoned 1 yr. after Treatment	36	....	....	29.82	11.21	1905	G. H. & S. A..	Bay View and San Leon, Tex........	....
6x8x8...	Sawed	Seasoned 1 yr. after Treatment	33	....	....	29.82	11.21	1905	G. H. & S. A..	Bay View and San Leon, Tex........	....

CONDITIONS							RESULTS						
% of Grade	Tie Plates		Kind of Spikes	Wt. of Rail, Lbs.	Ballast	Traffic Tons per Year	Date Inspected	Time of Service, Years	% Removed	Cause of Removal		Present Condition	Av'ge Life, Yrs.
	Kind	Size								Decay %	Wear %		
	None						1917	12	64.4				
	Glendon						1917	12	68.9				
			Screw				1917	12	41.7				
	Servis						1917	20	84				
	Servis						1917	20	70				
	Servis						1917	20	100				
	None						1917	12	59.4				
	Glendon						1917	12	16.7				
			Screw				1917	12	26.0				
	None						1917	12	55.7				
	Glendon						1917	12	36.2				
			Screw				1917	12	31.2				

DESCRIPTION OF MATERIAL								SERVICE			
Dimensions	Form	Preparation	No. of Ties in Test	Where Grown	Spacing in Track	Average Absorption Lbs. per Tie	Average Absorption Lbs. per Cu.ft.	Date placed	Name of R. R.	Location	Curve or Tangent
GUM — TUPELO ZINC CHLORIDE — BURNETT											
6x8x8...	Sawed	....	30	....	....	.6224	.234	1905	G. H. & S. A..	Bay View and San Leon, Tex.........	....
6x8x8...	Sawed	....	33	....	....	.6224	.234	1905	G. H. & S A...	Bay View & San Leon, Tex.........	....
6x8x8...	Sawed	....	46	....	....	.5955	.2239	1905	G. H. & S. A..	Bay View & San Leon, Tex.........	....
6x8x8...	Sawed	....	37	....	....	.5955	.2239	1905	G. H. & S. A..	Bay View and San Leon, Tex.........	....
6x8x8...	Sawed	....	30	....	....	.5955	.2239	1905	G. H. & S. A..	Bay View and San Leon, Tex.........	....
GUM — TUPELO ZINC CREOSOTE											
6x8x8...	Sawed	....	12	....	....	.5955 zn. cl. .538 creo.	.2238 zn. cl. .202 creo.	1905	G. H. & S. A..	Bay View and San Leon, Tex.........	....
6x8x8...	Sawed	....	16	....	....	.5955 zn. cl. .538 creo.	.2238 zn. cl. .202 creo.	1905	G. H. & S. A..	Bay View and San Leon, Tex.........	....
6x8x8...	Sawed	....	14	....	....	.5955 zn. cl. .538 creo.	.2238 zn. cl. .202 creo.	1905	G. H. & S. A..	Bay View and San Leon, Tex.........	....
HEMLOCK (EASTERN) CREOSOTE — OPEN TANK											
6x8x8...	Hewed	Various Seasoning	33	....	19 to rail......	......	......	1907	C. & N. W.Ry.	Janesville, Wis.	....
HEMLOCK (EASTERN) UNTREATED											
6x8x8...	Hewed	Soaked Seasoned 29 mos..	20	....	19 to rail......	......	......	1907	C. & N. W.....	Janesville, Wis.	....
6x8x8...	Hewed	Peeled Seasoned 26 mos..	20	....	19 to rail......	......	......	1907	C. & N. W.....	Janesville, Wis.	....
6x8x8...	Hewed	Peeled Seasoned 23 mos..	20	....	19 to rail......	......	......	1907	C. & N. W.....	Janesville, Wis.	....
6x8x8...	Hewed	Peeled Seasoned 26 mos..	20	....	19 to rail......	......	......	1907	C. & N. W.....	Janesville, Wis.	....
6x8x8...	Hewed	Peeled Seasoned 35 mos..	20	....	19 to rail......	......	......	1907	C. & N. W.....	Janesville, Wis.	....
6x8x8...	Hewed	Peeled Seasoned 11 mos..	50	....	19 to rail......	......	......	1907	C. & N. W.....	Janesville, Wis.	....
6x8x8...	Hewed	Peeled Seasoned 28 mos..	20	....	19 to rail......	......	......	1907	C. & N. W.....	Janesville, Wis.	....

CONDITIONS							RESULTS						
% of Grade	Tie Plates		Kind of Spikes	Wt. of Rail, Lbs.	Ballast	Traffic Tons per Year	Date Inspected	Time of Service, Years	% Removed	Cause of Removal		Present Condition	Av'ge Life, Yrs.
	Kind	Size								Decay %	Wear %		
	None						1917	12	100				8.0
	Glendo	n					1917	12	100				7.9
	None						1917	12	100				7.0
	Glendo	n					1917	12	100				7.0
							1917	12	100				7.0
							1917	12	91.6				
	None						1916	11	100				
	Glendo	n					1917	12	71.5				
	Wolhau	pter	Cut	90	Gravel	Light	1917	9½	0			70% Good	
	None		Cut	90	Sand	Light	1916	8½	100	Decay			6.5
	None		Cut	90	Sand	Light	1916	8½	100	Decay			6.6
	None		Cut	90	Sand	Light	1916	8½	100	Decay			6.6
	None		Cut	90	Sand	Light	1916	8½	100	Decay			6.4
	None		Cut	90	Sand	Light	1916	8½	95	Partly	decay		
	None		Cut	90	Sand	Light	1917	9½	88	Partly	decay		
	None		Cut	90	Sand	Light	1916	8½	100	Partly	decay		6.8

DESCRIPTION OF MATERIAL								SERVICE			
Dimensions	Form	Preparation	No. of Ties in Test	Where Grown	Spacing in Track	Average Absorption Lbs. per Tie	Average Absorption Lbs. per Cu.ft.	Date placed	Name of R. R.	Location	Curve or Tangent
HEMLOCK (EASTERN) ZINC CHLORIDE —— BURNETT											
6x8x8...	Hewed	Seasoned 10 mos...	25	....	19 to rail.......	......	0.26	1907	C. & N. W.....	Janesville, Wis	....
HEMLOCK (EASTERN) ZINC CREOSOTE —— CARD											
7x9x9.....	......	Seasoned 8 mos....	132	N. Mich...	18 to rail.......	10	..5# zn. cl. 2#creo	1908	C. M. & St. P.	Braymer, Mo..	2°...
HEMLOCK (EASTERN) ZINC TANNIN —— WELLHOUSE											
6x8x8...	Hewed	Peeled Seasoned 17 mos..	55	....	19 to rail.......	......	0.532	1907	C. & N. W.....	Janesville, Wis.	... ...
6x8x8...	Hewed	Peeled Seasoned 16½ mos..	40	....	19 to rail.......	......	0.564	1907	C. & N. W.....	Janesville, Wis.	.....
6x8x8...	Hewed	Peeled Seasoned 16 mos..	41	....	19 to rail.......	......	0.408	1907	C. & N. W.....	Janesville, Wis.	....
6x8x8...	Hewed	Peeled Seasoned 15 mos..	40	....	19 to rail.......	......	0.464	1907	C. & N. W.....	Janesville, Wis.	....
6x8x8...	Hewed	Peeled Seasoned 14 mos..	40	....	19 to rail.......	......	0.428	1907	C. & N. W.....	Janesville, Wis.	... .
6x8x8...	Hewed	Peeled Seasoned 12 mos..	37	....	19 to rail.......	......	0.376	1907	C. & N. W.....	Janesville, Wis.	....
6x8x8...	Hewed	Peeled Seasoned 11 mos..	41	....	19 to rail.......	......	0.340	1907	C. & N. W.....	Janesville, Wis.	....
6x8x8...	Hewed	Peeled Seasoned 11 mos..	40	....	19 to rail.......	......	0.384	1907	C. & N. W.....	Janesville, Wis.	....
6x8x8...	Hewed	Unpeeled Seasoned 17 mos..	24	....	19 to rail.......	......	0.728	1907	C. & N. W.....	Janesville, Wis.	....
6x8x8...	Hewed	Unpeeled Seasoned 16 mos..	25	....	19 to rail.......	......	0.60	1907	C. & N. W.....	Janesville, Wis.	....
6x8x8...	Hewed	Unpeeled Seasoned 12 mos..	40	....	19 to rail.......	.....	0.592	1907	C. & N. W.....	Janesville, Wis.	....
6x8x8...	Hewed	Soaked and Seasoned 17 mos..	47	....	19 to rail.......	......	0.516	1907	C. & N. W.....	Janesville, Wis.	....
6x8x8...	Hewed	Peeled Seasoned 17 mos..	40	....	19 to rail.......	......	0.468	1907	C. & N. W.....	Janesville, Wis.	....
6x8x8...	Hewed	Peeled Seasoned 16½ mos..	40	....	19 to rail.......	......	0.564	1907	C. & N. W.....	Janesville, Wis.	....

CONDITIONS							RESULTS						
% of Grade	Tie Plates		Kind of Spikes	Wt. of Rail, Lbs.	Ballast	Traffic Tons per Year	Date Inspected.	Time of Service, Years	% Removed.	Cause of Removal		Present Condition	Av'ge Life, Yrs.
	Kind	Size								Decay %	Wear %		
....	Wolhau	pter....	Cut............	90	Gravel....	Light......	1917	9½	16	Decay.	....	72% go	od
Level........	None..	....	Cut............	85	Burnt Gumbo..	Heavy....	1917	9	.....	....	....	Good..	......
....	Flat Se	llers....	Screw.........	90	Gravel....	Light....	1917	9½	10.9	Decay.	....	84% go	od
....	Flat Se	llers....	Screw.........	90	Gravel....	Light......	1917	9½	0	....	....	84% go	od
....	Flat Se	llers....	Screw.........	90	Gravel....	Light......	1917	9½	0	....	....	90% go	od
....	Flat Se	llers....	Screw.........	90	Gravel....	Light......	1917	9½	0	....	....	90% go	od
....	Flat Se	llers....	Screw.........	90	Gravel....	Light......	1917	9½	0	....	....	92% go	od
....	Flat Se	llers....	Screw.........	90	Gravel....	Light......	1917	9½	2.7	Decay.	....	81% go	od
....	Flat Se	llers....	Screw.........	90	Gravel....	Light......	1917	9½	9.8	Decay.	....	73% go	od
....	Flat Se	llers....	Screw.........	90	Gravel....	Light......	1917	9½	0	....	....	90% go	od
....	Flat Se	llers....	Screw.........	90	Gravel....	Light......	1917	9½	0	....	....	92% go	od
....	Flat Se	llers....	Screw.........	90	Gravel....	Light......	1917	9½	2.5	Decay.	....	96% go	od
....	Flat Se	llers....	Screw.........	90	Gravel....	Light......	1917	9½	2.5	Decay.	....	85% go	od
....	Flat Se	llers....	Screw.........	90	Gravel....	Light......	1917	9½	2.1	Decay.	....	83% go	od
....	Flat Se	llers....	Screw.........	90	Gravel....	Light......	1917	9½	2.5	Decay.	....	85% go	od
....	Flat Se	llers....	Screw.........	90	Gravel....	Light......	1917	9½	5.0	Decay.	....	82% go	od

DESCRIPTION OF MATERIAL								SERVICE			
Dimensions	Form	Preparation	No. of Ties in Test	Where Grown	Spacing in Track	Average Absorption		Date placed	Name of R. R.	Location	Curve or Tangent
						Lbs. per Tie	Lbs. per Cu.ft.				
HEMLOCK (EASTERN) —— (Continued)											
ZINC TANNIN —— WELLHOUSE											
6x8x8...	Hewed	Peeled Seasoned 16 mos..	40	....	....	.....	0.428	1907	C. & N. W.....	Janesville, Wis.	... ..
6x8x8...	Hewed	Peeled Seasoned 15 mos..	40	....	....	.....	0.512	1907	C. & N. W.....	Janesville, Wis.	.....
6x8x8...	Hewed	Peeled Seasoned 14 mos..	40	....	....	.....	0.432	1907	C. & N. W.....	Janesville, Wis.	... .
6x8x8...	Hewed	Peeled Seasoned 12 mos..	40	....	....	.....	0.452	1907	C. & N. W.....	Janesville, Wis.	... .
6x8x8...	Hewed	Peeled Seasoned 11 mos..	40	....	....	.....	0.352	1907	C. & N. W.....	Janesville, Wis.	....
6x8x8..	Hewed	Peeled Seasoned 11 mos..	39	....	....	.....	0.448	1907	C. & N. W.....	Janesville, Wis.	....
6x8x8...	Hewed	Unpeeled Seasoned 17 mos..	25	....	....	.....	0.728	1907	C. & N. W.....	Janesville, Wis.	....
6x8x8...	Hewed	Unpeeled Seasoned 14 mos..	25	....	....	.....	0.584	1907	C. & N. W.....	Janesville, Wis.	....
6x8x8...	Hewed	Unpeeled Seasoned 10 mos..	40	....	....	.....	0.512	1907	C. & N. W.....	Janesville, Wis.	....
6x8x8...	Hewed	Soaked and Seasoned 16 mos..	44	....	....	.....	0.476	1907	C. & N. W.....	Janesville, Wis.	....
6x8x8...	Hewed	Peeled Seasoned 17 mos..	39	....	....	.....	0.516	1907	C. & N. W.....	Janesville, Wis	....
6x8x8...	Hewed	Peeled Seasoned 16 mos..	41	....	....	.....	0.556	1907	C. & N. W....	Janesville, Wis.	... ..
6x8x8...	Hewed	Peeled Seasoned 15 mos..	43	....	....	.....	0.452	1907	C. & N. W.....	Janesville, Wis	.. .
6x8x8...	Hewed	Peeled Seasoned 14 mos..	39	....	....	.....	0.448	1907	C. & N. W.....	Janesville, Wis	. ....
6x8x8...	Hewed	Peeled Seasoned 13 mos..	40	....		.....	0.388	1907	C. & N. W.....	Janesville, Wis.	....
6x8x8...	Hewed	Peeled Seasoned 12 mos..	40	....	....	.....	0.376	1907	C. & N. W.....	Janesville, Wis.	....
6x8x8...	Hewed	Peeled Seasoned 11 mos..	40	....	....	.....	0.428	1907	C. & N. W.....	Janesville, Wis.	..... .
6x8x8...	Hewed	Peeled Seasoned 10 mos..	40	....	....	.....	0.388	1907	C. & N. W.....	Janesville, Wis.	....
6x8x8...	Hewed	Unpeeled Seasoned 16 mos..	25	....	....	.....	0.564	1907	C. & N. W. Ry.	Janesville, Wis.	.... .
6x8x8...	Hewed	Unpeeled Seasoned 13 mos...	21	....	....	.....	0.487	1907	C. & N. W. Ry.	Janesville, Wis.	. . ..

CONDITIONS							RESULTS						
% of Grade	Tie Plates		Kind of Spikes	Wt. of Rail, Lbs	Ballast	Traffic Tons per Year	Date Inspected	Time of Service, Years	% Removed	Cause of Removal		Present Condition	Av'ge Life, Yrs.
	Kind	Size								Decay %	Wear %		
....	Flat Se	llers....	Screw.........	90	Gravel....	Light......	1917	9½	0	....	....	90% go	od
....	Flat Se	llers....	Cut...........	90	Gravel....	Light......	1917	9½	0	....	....	95% go	od
....	Flat Se	llers....	Cut...........	90	Gravel....	Light......	1917	9½	0	....	....	97% go	od
....	Flat Se	llers....	Cut...........	90	Gravel....	Light......	1917	9½	2.5	Decay.	....	90% go	od
....	Flat Se	llers....	Cut...........	90	Gravel....	Light......	1917	9½	5.0	Decay.	....	80% go	od
....	Flat Se	llers....	Cut...........	90	Gravel....	Light......	1917	9½	0	....	....	97% go	od
....	Flat Se	llers....	Cut...........	90	Gravel....	Light......	1917	9½	0	....	....	92% go	od
....	Flat Se	llers....	Cut...........	90	Gravel....	Light......	1917	9½	0	....	....	100% go	od
....	Flat Se	llers....	Cut...........	90	Gravel....	Light......	1917	9½	0	....	....	95% go	od
....	Flat Se	llers....	Cut...........	90	Gravel....	Light......	1917	9½	2.3	Decay.	....	82% go	od
....	Wolhau	pter....	Cut...........	90	Gravel....	Light......	1917	9½	0	....	....	79% go	od
....	Wolhau	pter....	Cut...........	90	Gravel....	Light......	1917	9½	0	....	....	92% go	od
....	Wolhau	pter....	Cut...........	90	Gravel....	Light......	1917	9½	0	....	....	98% go	od
....	Wolhau	pter....	Cut...........	90	Gravel....	Light......	1917	9½	0	....	....	97% go	od
....	Wolhau	pter....	Cut...........	90	Gravel....	Light......	1917	9½	0	....	....	93% go	od
....	Wolhau	pter....	Cut...........	90	Gravel....	Light......	1917	9½	2.5	Decay.	....	74% go	od
....	Wolhau	pter....	Cut...........	90	Gravel....	Light......	1917	9½	2.5	Decay.	....	90% go	od
....	Wolhau	pter....	Cut...........	90	Gravel....	Light......	1917	9½	0	....	....	83% go	od
....	Wolhau	pter....	Cut...........	90	Gravel....	Light......	1917	9½	0	....	....	64% go	od
....	Wolhau	pter....	Cut...........	90	Gravel....	Light......	1917	9½	0	....	....	90% go	od

DESCRIPTION OF MATERIAL								SERVIC[E]			
Dimensions	Form	Preparation	No. of Ties in Test	Where Grown	Spacing in Track	Average Absorption Lbs. per Tie	Average Absorption Lbs. per Cu.ft.	Date placed	Name of R. R.	Location	Curve or Tangent
HEMLOCK (EASTERN) —— (Continued) ZINC TANNIN —— WELLHOUSE											
6x8x8...	Hewed	Unpeeled.. Seasoned 10 mos...	40	....	....	......	0.544	1907	C. & N. W. Ry.	Janesville, Wis.	....
6x8x8...	Hewed	Soaked Seasoned 15 mos...	49	....	....	......	0.50	1907	C. & N. W. Ry.	Janesville, Wis.	....
6x8x8...	Hewed	Peeled and Unpeeled Seasoned 10 mos..	53	....	....	......	0.356	1907	C. & N. W. Ry.	Janesville, Wis.	....
6x8x8...	Hewed	Peeled and Unpeeled Seasoned 10 mos..	51	....	....	......	0.356	1907	C. & N. W. Ry.	Janesville, Wis.	....
6x8x8...	Hewed	Peeled and Unpeeled Seasoned 10 mos..	51	....	....	......	0.436	1907	C. & N. W. Ry.	Janesville, Wis.	....
6x8x8...	Hewed	....	16197	Mich......	....	1.5	0.50	1900	C. R. I. & P....	Sibley, Iowa...	Tangent
....	....	....	142	....	....	......	0.443 zn. cl. 0.072 Gel. 0.086 Tan.	1905	C & N. W.....	Clyman, Wis..	....
JUNIPER CREOSOTE —— FULL CELL											
....	Hewed	Peeled Seasoned 10 mos..	25	....	....	......	8	1897	N. & S........	Norfolk Div...	2°
....	Hewed	Seasoned 5 mos. after treatment	75	....	....	......	8	1897	N. & S........	Norfolk Div...	Tangent
JUNIPER UNTREATED											
....	Hewed	....	200	....	....	......	......	1897	N. & S........	Norfolk Div...	Tangent
....	Hewed	Seasoned 14 mos...	100	....	....	......	......	1897	N. & S........	Norfolk Div...	Tangent
....	Hewed	Seasoned 14 mos...	120	....	....	......	......	1897	N. & S........	Norfolk Div. .	Tangent
....	Hewed	Seasoned 14 mos...	100	....	....	......	......	1897	N. & S........	Norfolk Div...	Tangent
....	Hewed	Seasoned 14 mos...	100	....	....	......	......	1897	N. & S........	Norfolk Div...	Tangent
....	Hewed	Seasoned 14 mos...	100	....	....	......	......	1897	N. & S........	Norfolk Div...	Tangent
....	Hewed	Seasoned 14 mos...	100	....	....	......	......	1897	N. & S........	Norfolk Div...	Tangent
....	Hewed	Seasoned 14 mos...	100	....	....	......	......	1897	N. & S........	Norfolk Div...	Tangent

CONDITIONS							RESULTS						
% of Grade	Tie Plates		Kind of Spikes	Wt. of Rail, Lbs.	Ballast	Traffic Tons per Year	Date Inspected	Time of Service, Years	% Removed	Cause of Removal		Present Condition	Av'ge Life, Yrs.
	Kind	Size								Decay %	Wear %		
....	Wolhau	pter....	Cut...........	90	Gravel....	Light.....	1917	9½	0	....	....	93% Good	......
....	Wolhau	pter....	Cut...........	90	Gravel....	Light.....	1917	9½	0	....	....	86% Good	......
....	Wolhau	pter....	Cut...........	90	Gravel....	Light.....	1917	9½	7.6	Decay	....	62% Good	......
....	Wolhau	pter....	Cut...........	90	Gravel....	Light.....	1917	9½	5.9	Decay	....	75% Good	......
....	Wolhau	pter....	Cut...........	90	Gravel....	Light.....	1917	9½	3.9	Decay	....	81% Good	......
....	None..	....	Cut...........	60	Gravel and Cinders.	Light.....	1917	17	42.8	Various	....	Fair...	......
....	....	....	....	......	....	....	1914	9	30.3	....	....	....	......
....	....	....	....	......	....	....	1917	20	76	....	....	....	......
....	....	....	....	......	....	....	1917	20	51	....	....	....	......
....	....	....	....	......	....	....	1917	20	100	....	....	....	12.2
....	Goldie	....	....	......	....	....	1917	20	99	....	....	....	13
....	....	....	....	......	....	....	1917	20	99	....	....	....	14
....	....	....	....	......	....	....	1917	20	100	....	....	....	14.6
....	....	....	....	......	....	....	1917	20	99	....	....	....	13.9
....	Lags a Clips	nd	....	......	....	....	1917	20	99	....	....	....	13.2
....	Felt...	....	....	......	....	....	1917	20	100	....	....	....	12.9
....	....	....	....	......	....	....	1917	20	99	....	....	....	13.2
											Averag	e......	13.2

DESCRIPTION OF MATERIAL								SERVICE			
Dimensions	Form	Preparation	No. of Ties in Test	Where Grown	Spacing in Track	Average Absorption Lbs. per Tie	Average Absorption Lbs. per Cu.ft.	Date placed	Name of R. R.	Location	Curve or Tangent
LARCH — WESTERN UNTREATED.											
7x9x8	Hewed	Seasoned	27	Mountains	18 to rail			1907	N. P	Plains, Mont	Tangent
7x9x8	Hewed	Green	96	Mountains	18 to rail			1907	N. P	Plains, Mont	Tangent
7x9x8	Hewed	Seasoned	90	Mountains	18 to rail			1907	N. P	Plains, Mont	Tangent
7x9x8	Hewed	Green	91	Mountains	18 to rail			1907	N. P	Plains, Mont	Tangent
7x9x8	Hewed	Seasoned	90	Mountains	18 to rail			1907	N. P	Plains, Mont	Tangent
7x9x8	Hewed	Green	90	Mountains	18 to rail			1907	N. P	Plains, Mont	Tangent
7x9x8	Hewed	Seasoned	90	Mountains	18 to rail			1907	N. P	Plains, Mont	Tangent
7x9x8	Hewed	Green	91	Mountains	18 to rail			1907	N. P	Plains, Mont	Tangent
7x9x8	Hewed	Seasoned	90	Mountains	18 to rail			1907	N. P	Plains, Mont	Tangent
7x9x8	Hewed	Green	91	Mountains	18 to rail			1907	N. P	Plains, Mont	Tangent
7x9x8	Hewed	Seasoned	90	Mountains	18 to rail			1907	N. P	Plains, Mont	Tangent
7x9x8	Hewed	Green	92	Mountains	18 to rail			1907	N. P	Plains, Mont	Tangent
7x9x8	Hewed	Seasoned	91	Mountains	18 to rail			1907	N. P	Plains, Mont	Tangent
	Slabbed		1231					1911	G. N	Butte Div	Tang 70° Curve30°
	Sawed triang	ular	1469					1911	G. N	Butte Div	Tang.70° Curve30°
	Sawed square		1277					1911	G. N	Butte Div	Tang.70° Curve30°
LARCH — WESTERN ZINC CHLORIDE — BURNETT											
7x9x8	Hewed	Seasoned	101	Mountains	18 to rail		0.874	1907	N. P	Plains, Mont	Tangent
7x9x8	Hewed	Seasoned	92	Mountains	18 to rail		0.874	1907	N. P	Plains, Mont	Tangent
	Slabbe	d	1273				0.50	1911	G. N		Tang. 70° Curve30°
	Slabbe	d	1433				0.75	1911	G. N		Tang. 70° Curve30°
	Sawed	square	1318				0.50	1911	G. N		Tang. 70° Curve30°
	Sawed	triangular	2053				0.75	1911	G. N		Tang. 70° Curve30°
	Sawed	triangular	1228				0.50	1911	G. N		Tang. 70° Curve30°
MAPLE CREOSOTE — FULL CELL											
6x8x8		Seasoned 6 to 18 mos.	50	N. E. Wis	18 to rail		12	1911	C. M. & St. P.	Hartford, Wis	Tangent
6x8x8		Seasoned 6 to 18 mos.	50	N. E. Wis	18 to rail		12	1911	C. M. & St. P	Hartford, Wis	Tangent

ONDITIONS							RESULTS						
% of Grade	Tie Plates		Kind of Spikes	Wt. of Rail, Lbs.	Ballast	Traffic Tons per Year	Date Inspected.	Time of Service, Years	% Removed.	Cause of Removal		Present Condition	Av'ge Life, Yrs.
	Kind	Size								Decay %	Wear %		
17..........	Wooden and Wolhaupter		Screw and Cut.	85	Gravel....	8,270,506	1915	8.33	100	....	....	....	6.9
17..........	Wooden and Wolhaupter		Screw and Cut.	85	Gravel....	8,270,506	1915	8.33	100	....	....	....	6.9
17..........	Wooden and Wolhaupter		Screw and Cut.	85	Gravel....	8,270,506	1915	8.33	100	....	....	....	7.2
17..........	Wolhaupter....		Cut..........	85	Gravel....	8,270,506	1915	8.33	100	....	....	....	7.2
17..........	Sellers.	....	Cut..........	85	Gravel....	8,270,506	1915	8.33	100	....	....	....	7.5
17..........	Sellers.	....	Cut..........	85	Gravel....	8,270,506	1915	8.33	100	....	....	....	7.5
17..........	Sellers.	....	Cut..........	85	Gravel....	8,270,506	1915	8.33	100	....	....	....	7.3
17..........	Sellers.	....	Cut..........	85	Gravel....	8,270,506	1915	8.33	100	....	....	....	7.4
17..........	Sellers.	....	Screw and Cut.	85	Gravel....	8,270,506	1916	9.33	100	....	....	....	7.4
17..........	Sellers.	....	Screw and Cut.	85	Gravel....	8,270,506	1915	8.33	100	....	....	....	7.4
17..........	Sellers.	....	Screw.........	85	Gravel....	8,270,506	1916	9.33	100	....	....	....	7.8
17..........	Sellers.	....	Screw.........	85	Gravel ..	8,270,506	1916	9.33	100	....	....	....	7.8
17..........	Sellers.	....	Cut..........	85	Gravel....	8,270,506	1915	8.33	100	....	....	....	7.3
....	Goldie J. G. 58	6½x8½	Cut..........	90	Gravel....	....	1917	6.33	17	Decay	....	Poor...	......
....	Goldie J. G. 58	6½x8½	Cut..........	90	Gravel....	....	1917	6.33	37	Decay and Split..........		Very Poor..	......
....	Goldie J. G. 58	6½x8½	Cut..........	90	Gravel....	....	1917	6.33	31	Decay	....	Fair...	......
17..........	Sellers.	....	Screw.........	85	Gravel....	8,270,506	1916	9.3	1.0	....	....	59% good	
17..........	Sellers.	....	Screw and cut.	85	Gravel....	8,270,506	1916	9.3	10.9	....	....	61% good	
....	Goldie	6½x8½	Cut...........	90	Gravel....	....	1917	6.3	0	....	....	Good..	......
....	Goldie	6½x8½	Cut...........	90	Gravel....	....	1917	6.3	0	....	....	Good..	.....
....	Goldie	6½x8½	Cut...........	90	Gravel....	....	1917	6.3	3	Decay.	....	Fair...	......
....	Goldie	6½x8½	Cut...........	90	Gravel....	....	1917	6.3	.2	Decay.	....	Good..	......
....	Goldie	6½x8½	Cut...........	90	Gravel....	....	1917	6.3	1	Decay.	....	Good..	......
evel..	Flat steel....		Screw	90	Gravel.	Heavy....	1917	6	0	......	......	93% good	
evel.	None.	....	Cut...........	90	Gravel...	Heavy....	1917	6	0	....	......	93% good	

DESCRIPTION OF MATERIAL								SERVICE			
Dimensions	Form	Preparation	No. of Ties in Test	Where Grown	Spacing in Track	Average Absorption Lbs. per Tie	Average Absorption Lbs. per Cu.ft.	Date placed	Name of R. R.	Location	Curve or Tangent
MAPLE CREOSOTE — RUEPING											
6x8x8...	....	Seasoned 6 to 18 mos.	50	N. E. Wis.	18 to rail......	......	4.9	1911	C. M. & St. P.	Hartford, Wis.	Tangent
6x8x8...	....	Seasoned 6 to 18 mos.	50	N. E. Wis.	18 to rail......	......	4.9	1911	C. M. & St. P..	Hartford, Wis.	Tangent
MAPLE SEMI-REFINED — FULL CELL											
6x8x8...	....	Seasoned 6 to 18 mos.	50	N. E. Wis..	18 to rail......	......	12.6	1911	C. M. & St. P..	Hartford, Wis..	Tangent
6x8x8...	....	Seasoned.. 6 to 18 mos.	50	N. E. Wis.	18 to rail......	......	12.6	1911	C. M. & St. P..	Hartford, Wis..	Tangent
MAPLE UNTREATED											
6x8x8...	....	Seasoned 6 to 18 mos.	50	N. E. Wis..	18 to rail......	......	......	1911	C. M. & St. P..	Hartford, Wis..	Tangent
6x8x8...	....	Seasoned..	50	N. E. Wis..	18 to rail......	......	......	1911	C. M. & St. P..	Hartford, Wis.	Tangent
MAPLE ZINC CHLORIDE — BURNETT											
6x8x8...	....	Seasoned 6 to 18 mos.	50	N. E. Wis..	18 to rail......	......	0.5	1911	C. M. & St. P..	Hartford, Wis.	Tangent
6x8x8...	....	Seasoned 6 to 18 mos.	50	N. E. Wis..	18 to rail......	......	0.5	1911	C. M. & St. P..	Hartford, Wis.	Tangent
MAPLE ZINC CREOSOTE — CARD											
7x9x9...	....	Seasoned 6 to 18 mos.	50	N. E. Wis..	18 to rail......	......	0.37 zn. cl. 3.1# creo.	1911	C. M. & St. P..	Hartford, Wis.	Tangent
7x9x9...	....	Seasoned 6 to 18 mos.	50	N. E. Wis..	18 to rail......	......	0.37 zn. cl. 3.1# creo.	1911	C. M & St. P..	Hartford, Wis.	Tangent.
7x9x9...	....	Seasoned 8 mos....	464	N. Mich...	18 to rail......	10	0.5 zn. cl. 2#creo	1908	C. M. & St. P..	Braymer, Wis.	2°.
MAPLE ZINC CREOSOTE — TWO MOVEMENT											
6x8x8...	....	Seasoned 6 to 18 mos.	50	N. E. Wis..	18 to rail......	......	15.5# Emulsion	1911	C. M. & St. P	Hartford, Wis.	Tangent
6x8x8...	....	Seasoned 6 to 18 mos	50	N. E. Wis.	18 to rail......	......	15.5# Emulsion	1911	C. M. & St. P..	Hartford, Wis.	Tanger

CONDITIONS							RESULTS						
% of Grade	Tie Plates		Kind of Spikes	Wt. of Rail, Lbs.	Ballast	Traffic Tons per Year	Date Inspected	Time of Service, Years	% Removed	Cause of Removal		Present Condition	Av'ge Life, Yrs.
	Kind	Size								Decay %	Wear %		
Level	Flat steel		Screw	90	Gravel	Heavy	1917	6	0			91% good	
Level	None		Cut	90	Gravel	Heavy	1917	6	0			94% good	
Level	Flat steel		Screw	90	Gravel	Heavy	1917	6	0			97% good	
Level	None		Cut	90	Gravel	Heavy	1917	6	0			97% good	
Level	Flat steel		Screw	90	Gravel	Heavy	1917	6	36	Decay		90% good	
Level	None		Cut	90	Gravel	Heavy	1917	6	36	Decay		90% good	
Level	Flat steel		Screw	90	Gravel	Heavy	1917	6	0			97% good	
Level	None		Cut	90	Gravel	Heavy	1917	6	0			97% good	
Level	Flat steel		Screw	90	Gravel	Heavy	1917	6	0			99% good	
Level	None		Cut	90	Gravel	Heavy	1917	6	0			99% good	
	None		Cut	85	Burnt gumbo	Heavy	1917	9	0			99% good	
Level	Flat steel		Screw	90	Gravel	Heavy	1917	6	0			99% good	
Level	None		Cut	90	Gravel	Heavy	1917	6	0			99% good	

DESCRIPTION OF MATERIAL								SERVICE			
Dimensions	Form	Preparation	No. of Ties in Test	Where Grown	Spacing in Track	Average Absorption Lbs. per Tie	Average Absorption Lbs. per Cu.ft.	Date placed	Name of R. R.	Location	Curve or Tangent
MAPLE — SOFT CRUDE OIL											
....	....	....	6	....	....	.....	.....	1911	C. B. & Q.....	Baders, Ill.....	....
OAK — MIXED ZINC TANNIN — WELLHOUSE											
6x8x8...	Hewed	Not bored for spikes	3000	....	....	.....	.....	1900	C.& W.I.R.R..	Dalton Branch.	Tang.and 3° curve
6x8x8...	Hewed	Not bored for spikes	4000	....	....	.....	.....	1901	C.& W.I.R.R..	Dalton Branch.	Tang.and 3° curve
6x8x8...	Hewed	Not bored for spikes	1225	....	....	.....	.....	1903	C.& W.I.R.R..	Dalton Branch.	Tang.and 3° curve
6x8x8...	Hewed	Not bored for spikes	272	....	....	.....	.....	1899	C.& W.I.R.R..	Dalton Branch.	Tang.and 3° curve
6x8x8...	Hewed	Not bored for spikes	1088	....	....	.....	.....	1902	C.& W.I.R.R..	Dalton Branch.	Tang.and 3° curve
OAK — RED CREOSOTE											
8x7x9...	Sawed.	Seasoned..	68	Ala........	....	.....	5.54	1910	T. C. I. & R...	Ensley, Ala....	....
....	Hewed	Varied.....	8	....	....	.....	.....	1905	St.L.-S.F......	Pacific, Mo....	....
OAK — RED CREOSOTE — FULL CELL											
....	....	....	97	....	....	.....	8.34	1908	C. B. & Q.....	Lines east.....	....
6x8x8...	Hewed	Seasoned..	50	....	18 to rail......	.....	10.9	1911	C. M. & St. P.	Hartford, Wis.	Tangent.
6x8x8...	Hewed	Seasoned..	52	....	18 to rail......	.....	10.9	1911	C. M. & St. P.	Hartford, Wis.	Tangent.
6x8x8...	Sawed and Hewed	Varied.....	76	....	....	6.42	.....	1905	St. L.-S. F.....	Pacific, Mo....	Tangent.
OAK — RED CREOSOTE — GIUSSANI											
6x8x8...	Sawed and Hewed	Varied.....	43	....	....	0.75#–10#–15 per	1.0# z #creo. tie	n. 1905	St. L.-S.F.....	Pacific, Mo....	Tangent.
OAK — RED CREOSOTE — LIVE STEAM IN SUPERHEATED COILS											
6x8x8...	Sawed and Hewed	....	24	....	....	6 to 42	.....	1905	St. L.-S. F.....	Pacific, Mo....	Tangent

CONDITIONS							RESULTS						
% of Grade	Tie Plates Kind	Tie Plates Size	Kind of Spikes	Wt. of Rail, Lbs.	Ballast	Traffic Tons per Year	Date Inspected	Time of Service, Years	% Removed	Cause of Removal Decay %	Cause of Removal Wear %	Present Condition	Av'ge Life, Yrs.
....	Yes, ex der j	cept un- oints....	Cut...........	75	Gravel....	....	1917	6	100	....	....	....	......
.05	Sellers.	....	Cut...........	80	Slag.......	....	1916	16	86	....	....	Fair...	......
05...........	Sellers.	....	Cut...........	80	Slag.......	....	1916	15	86	....	....	Fair...	......
.05...........	Sellers.	....	Cut...........	80	Slag.......	....	1916	13	99.7	....	....	Fair...	......
.05...........	Sellers.	....	Cut...........	80	Slag.......	....	1916	17	79	....	....	Fair...	......
05...........	Sellers.	....	Cut...........	80	Slag.......	....	1916	14	86	....	....	Fair...	......
....	Goldie	....	Cut...........	......	Sand and	Dirt........	1917	7	30.9	Decay.	....	19% go	od
....	....	....	....	85and 90	....	....	1917	12	25.0	....	....	....	.....
....	On cur	ves.....	Cut...........	90	Gravel....	....	1917	9	1	Split...	....	....	.....
Level.........	Yes...	....	Screw.........	90	Gravel....	Heavy....	1917	6	......	....	....	94% go	od
Level.........	None..	....	Cut...........	90	Gravel....	Heavy....	1917	6	......	....	....	94% go	od
....	....	8¾x6½	Cut...........	85–90	Gravel....	9,000,000	1917	12	10.5	....	....	Fair...	......
....	....	8¾x6½	Cut...........	85–90	Gravel....	9,000,000	1917	12	41.9	....	....	Fair...	......
....	....	8¾x6½	Cut...........	85–90	Gravel....	9,000,000	1917	12	8.3	....	....	....	.....

DESCRIPTION OF MATERIAL								SERVICE			
Dimensions	Form	Preparation	No. of Ties in Test	Where Grown	Spacing in Track	Average Absorption Lbs. per Tie	Average Absorption Lbs. per Cu.ft.	Date placed	Name of R. R.	Location	Curve or Tangent
OAK — RED CREOSOTE — LOWRY											
7x0x8...	Hewed	Seasoned 6 mos....	46	Minn......	19 to rail.......	22.8	6.5	1908	N. P..........	Sumner, Wash.	Tangent.
OAK — RED CREOSOTE — NO STEAMING											
....	Sawed and Hewed	Varied.....	83	....	....	11to30	......	1905	St. L.-S. F.....	Pacific, Mo....	....
OAK — RED CREOSOTE — RUEPING											
6x8x8...	Hewed	Seasoned 2 years..	752	....	....	12.6	......	1906	St. L.-S F ..	St Clair. Mo..	....
6x8x8...	Sawed and Hewed	Varied.....	40	....	....	7 to 21.5	......	1905	St. L.-S. F.....	Pacific, Mo....	Tangent.
6x8x8...	Hewed	Seasoned..	50	....	18 to rail.......	......	5.3	1911	C. M. & St. P.	Hartford, Wis.	Tangent
6x8x8...	Hewed	Seasoned..	50	....	18 to rail.......	......	5.3	1911	C. M. & St. P.	Hartford, Wis	Tangent.
OAK — RED SEMI-REFINED OIL — FULL CELL											
6x8x8...	....	Seasoned..	50	....	18 to rail......	......	7.3	1911	C. M. & St. P.	Hartford, Wis.	Tangent.
6x8x8...	....	Seasoned..	50	....	18 to rail......	......	7.3	1911	C. M. & St. P.	Hartford, Wis.	Tangent.
OAK — RED UNTREATED											
....	....	....	50	....	18 to rail......	......	......	1908	C. B. & Q.....	Lines East.....	....
6x8x8...	....	Seasoned 10 mos...	50	Tenn......	18 to rail......	......	......	1911	C. M. & St. P.	Hartford, Wis.	Tangent
6x8x8...	....	Seasoned 10 mos...	50	Tenn......	18 to rail......	......	......	1911	C. M. & St. P.	Hartford, Wis.	Tangent.

CONDITIONS							RESULTS						
% of Grade	Tie Plates		Kind of Spikes	Wt. of Rail, Lbs.	Ballast	Traffic Tons per Year	Date Inspected	Time of Service, Years	% Removed	Cause of Removal		Present Condition	Av'ge Life, Yrs.
	Kind	Size								Decay %	Wear %		
...	Flat	6"x8½"	Cut...	90	Gravel...	Heavy...	1917	9	...	...	...	Good..	...
...	...	8¾"x6½"	Cut...	85–90	Gravel...	9,000,000	1917	12	13.3	...	...	...	...
...	...	8¾"x6½"	Cut...	Orig. 75# 90# since 1909	Chatts ballast put in on gravel.	8,300,000	1917	11	19.5	8.4	11.1	...	...
...	...	8¾"x6½"	Cut...	85–90	Gravel...	9,000,000	1917	12	10.0	...	...	...	...
Level...	None..	...	Cut...	90	Gravel...	Heavy...	1917	6	0	...	...	94% good	
Level...	Flat steel	6x8...	Screw...	90	Gravel...	Heavy...	1917	6	0	...	...	94% good	
Level...	Flat steel	6"x8"	Screw...	90	Gravel...	Heavy...	1917	6	...	...	...	99% Good	...
Level...	None .	...	Cut...	90	Gravel...	Heavy...	1917	6	...	...	...	99% Good	...
...	...	...	Cut...	90	Gravel..	...	1917	9	96	...	...	...	...
Level...	Flat steel	6"x8"	Screw...	90	Gravel...	Heavy...	1917	6	2	Decay	...	98% affected by decay	
Level...	None..	...	Cut...	90	Gravel ...	Heavy...	1917	6	2	Decay	...	98% affected by decay	

DESCRIPTION OF MATERIAL								SERVICE			
Dimensions	Form	Preparation	No. of Ties in Test	Where Grown	Spacing in Track	Average Absorption Lbs. per Tie	Average Absorption Lbs. per Cu.ft.	Date placed	Name of R. R.	Location	Curve or Tangent
OAK — WHITE — UNTREATED											
7x8x8...	Hewed	Seasoned..	117740		22″			1912	M. P. Ry.	Marianna cut-off, Ark.	
7x8x8...	Sawed		65725	N. Y. and Penn.	21″			1902	P. S. & N.	New York.	42% C... 58% T...
7x8x8...		Seasoned..	20219	N. Y. and Penn.	21″			1902	P. S. & N.	Penn.	50% T... 50% C...
7x8x8...	Hewed	Seasoned..	137000		18 to rail			1901 to 1906	Wash. Term.	Wash., D. C.	
			50		19 to rail			1907	C. & N. W.	Janesville, Wis.	
6x8x8...	Hewed		500	Kan.	18 to rail			1903	C. M. & St. P.	Wash., Iowa.	Tangent.
8x7x9...	Sawed.	Seasoned..	35	Ala.				1910	T. C. I. & R.	Ensley, Ala.	
OAK — WHITE ZINC CREOSOTE — CARD											
			188					1908	C. B. & Q.	Lines East.	
		Seasoned..	193					1908	C. B. & Q.	Lines West.	
PINE — JACK CREOSOTE — LOWRY											
7x9x8...	Hewed	Seasoned Not bored for spikes	45	Minn.	19 to rail	22.8	6.5	1908	N. P.	Sumner, Wash.	Tangent.
PINE — LOBLOLLY CREOSOTE — FULL CELL											
7x8x8½..	Sawed and Hewed	Seasoned Bored for screw spikes....	2743			30 to 40	8.0 to 10.0	1910	Pa. System.	Wooster, Ohio	3°-5° and Tang.
PINE — LOBLOLLY — SAP CREOSOTE — FULL CELL											
7x9x8½..	Hewed	Seasoned 6 mos..	1000			35	10	1907	G. R. R.	Union Pt., Ga.	
7x9x8½.	Hewed	Seasoned 10 mos.	1000			35	10	1907	G. R. R.	Barnett, Ga.	

CONDITIONS							RESULTS						
% of Grade	Tie Plates		Kind of Spikes	Wt. of Rail, Lbs.	Ballast	Traffic Tons per Year	Date Inspected	Time of Service, Years	% Removed	Cause of Removal		Present Condition	Av'ge Life, Yrs.
	Kind	Size								Decay %	Wear %		
....	None..	....	Cut...........	63 &75	Sand......	21,478,431	1917	5	65	Decay Broke	and n.......	Fair...	......
1.3...........	Wolhau	pter....	Cut...........	85	Slag.......	4,000,000	1917	15	76	Decay	....	Good..	......
1.5...........	Wolhau	pter....	Cut...........	85	Gravel and Slag.....	4,000,000	1917	15	63	Decay	....	Fairly Good	......
....	P. R. bottom	R. Flat	Cut...........	85	Stone and Cinder...	1,460,000	1917	11-13	97	....	....	....	......
....	None..	....	Cut...........	90	Gravel....	....	1917	9.5	38	Decay	....	62% affect	ed
Level.........	None..	....	Cut...........	85	Gravel....	Heavy....	1917	14	79	Decay	....	Good..	......
....	Goldie Curve	on s only..	Cut...........	......	Sand and dirt.....	....	1917	7	71.4	Decay	....	3% Good	...
....	Yes...	....	....	90	Gravel....	....	1917	9	12	Decay and B	, Split roken..	Excelle	nt....
....	Yes...	....	....	90	Gravel....	....	1917	9	7½	Decay and B	, Split roken...	Excelle	nt...
....	Flat...	6"x8½".	Cut...... ...	90	Gravel....	Heavy....	1917	9	0	.... .	......	Good.	.....
0.8...........	Flat bo	ttom...	Cut and screw.	100	Stone......	20,000,000	1917	7	100	Placed track	in yard	Good.	.....
....	None..	....	Cut...........	65	Cinder.....	900,000	1916	9	3.3	Decay.	....	Good..	....
....	None..	....	Cut...........	65	Cinder.....	300,000	1916	9	2.3	Decay.	....	Good..	.....

DESCRIPTION OF MATERIAL								SERVICE			
Dimensions	Form	Preparation	No. of Ties in Test	Where Grown	Spacing in Track	Average Absorption Lbs. per Tie	Average Absorption Lbs. per Cu.ft.	Date placed	Name of R. R.	Location	Curve or Tangent
PINE — SAP ZINC CHLORIDE — BURNETT											
7x9x8...	Hewed	Seasoned 3 mos. after treatment..	333	....	....	1.443	.4122	1905	G. H. & S. A..	San Leon and Bay View, Tex.	....
7x9x8...	Hewed	Seasoned 3 mos. after treatment..	334	....	....	1.443	.4122	1905	G. H. & S. A..	San Leon and Bay View, Tex.	....
PINE — SHORTLEAF CREOSOTE											
8x7x9...	Sawed.	Seasoned..	113	Ala........	....	......	7	1910	T. C. I. & R...	Ensley, Ala....	....
PINE — SHORTLEAF CREOSOTE — RUEPING											
8x7x8½..	Sawed and Hewed	Seasoned Bored for spikes...	2494	Ky........	....	22½	6.8	1907	Pa. System....	Scio, Ohio.....	Tangent.
PINE — SHORTLEAF CRESOL CALCIUM											
8x7x9...	Sawed	Seasoned..	104	Ala........	....	......	1.15	1910	T. C. I. & R...	Ensley, Ala....	....
8x7x9...	Sawed	Seasoned..	103	Ala........	....	......	0.85	1910	T. C. I. & R...	Ensley, Ala....	....
8x7x9...	Sawed	Seasoned..	98	Ala........	....	......	0.51	1910	T. C. I. & R...	Ensley, Ala....	....
8x7x9...	Sawed	Seasoned..	93	Ala........	....	......	0.27	1910	T. C. I. & R...	Ensley, Ala....	....
PINE — SHORTLEAF ZINC CHLORIDE — BURNETT											
6x8x8...	Hewed	Seasoned..	500	....	22"...........	1⅕	0.5	1907	C. M. & St. P.	Morristown, S. D.........	Tangent.
6x8x8...	Sawed.	Seasoned..	500	Texas......	18 to rail.......	1⅕	0.5	1903	C. M. & St. P.	Washington, Iowa	Tangent.
PINE — SOUTHERN YELLOW CREOSOTE											
7x9x8...	....	....	6000	....	....	......	10	1894	N.Y.N.H.&H.	Fairhaven Tunnel.......	
7x9x8...	Hewed	....	500	....	....	......	......	1906	N.Y.N.H.&H.	Fairhaven Tunnel.......	
7x9x8...	Hewed	....	200	....	....	......	......	1907	N.Y.N.H.&H.	Fairhaven Tunnel.......	

CONDITIONS							RESULTS						
% of Grade	Tie Plates		Kind of Spikes	Wt. of Rail, Lbs.	Ballast	Traffic Tons per Year	Date Inspected	Time of Service, Years	% Removed	Cause of Removal		Present Condition	Av'ge Life, Yrs.
	Kind	Size								Decay %	Wear %		
....	Glendo	n.......	....	....	....	....	1917	12	100	....	....	....	5 6
....	None..	....	....	....	....	....	1916	11	100	....	....	....	5.5
....	Goldie.	....	Cut.......	....	Sand and d	irt.......	1917	7	6.2	Decay.	....	Good.	....
.10.......	Flat bo 6"x9".	ttom	Cut and screw.	100	Stone.	....	1917	10	65	Wear..	....	Sound.	....
....	Goldie.	....	Cut.......	....	Sand and d	irt.......	1917	7	54.8	Decay.	....	3% goo	l
....	Goldie.	....	Cut.......	....	Sand and d	irt.......	1917	7	80.6	Decay.	....	1% goo	d
....	Goldie.	....	Cut.......	....	Sand and d	irt.......	1917	7	91	Decay.	....	2% goo	d
....	Goldie.	....	Cut.......	....	Sand and d	irt.......	1917	7	96.8	Decay.	....	....	....
0 6.......	Mallea 6x8...	ble	Cut.......	85	Sand to 60% burnt clay	5,562,600	1917	10	8.6	......	....	....	....
Level.......	Mallea 6x8..	ble	Cut.......	90	Gravel....	Heavy....	1917	14	27	Decay.	....	....	....
....	None..	....	Cut.......	100	Stone......	Heavy....	1916	22	99.6	....	....	....	....
....	....	....	Cut.......	100	Stone......	Heavy....	1916	10	0	....	....	....	....
....	....	....	Cut.......	100	Stone......	Heavy....	1916	9	0	....	....	....	....

DESCRIPTION OF MATERIAL								SERVICE			
Dimensions	Form	Preparation	No. of Ties in Test	Where Grown	Spacing in Track	Average Absorption Lbs. per Tie	Average Absorption Lbs. per Cu.ft.	Date placed	Name of R. R.	Location	Curve or Tangent
PINE — SOUTHERN YELLOW CREOSOTE — FULL CELL											
7x9x8½	Hewed	Unseasoned	1274	So. Miss	22"	44.6	12	1907	L. & N. Ry	Pawlee Creek, Miss	30'
6x10x8			868			4.42 Gal.	1.326 Gal.	1909	G. H. & S. A.	Bay View and San Leon, Tex.	
			205				12	1906	G. H. & S. A.	Salix, La.	
7x9x9	Hewed		285				1.3	1906	G. H. & S. A.	Lafayette and Scott	
6x9x8			849		16 to 33' rail		1.3	1911	G. H. & S. A.	Olivier, New Iberia	
6x10x8			295		14 to 33' rail		1.3	1911	G. H. & S. A.	Olivier, New Iberia	
6x10x8			731		16 to 33' rail		1.3	1911	G. H. & S. A.	Olivier, New Iberia	
6x10x8			1963		18 to 33' rail		1.3	1911	G. H. & S. A.	Olivier, New Iberia	
PINE — SOUTHERN YELLOW CREOSOTE — RUEPING											
	Hewed	Seasoned	304				4.56	1905	A. T. & S. F.	Marceline, Mo.	
	Sawed	Seasoned	572				3.93	1905	A. T. & S. F.	Argonia, Kan.	
	Hewed	Air seasoned	44				4.56	1905	A. T. & S. F.	Sutton, Kan.	
	Hewed	Air seasoned	190				4.56	1904	A. T. & S. F.	Ponca City, Okla.	
	Sawed	Air seasoned	275				3.93	1904	A. T. & S. F.	Bliss, Okla.	
	Sawed	Air seasoned	366				3.93	1904	A. T. & S. F.	Perry, Okla.	
	Hewed	Air seasoned	27				4.56	1904	A. T. & S. F.	Perry, Okla.	
	Sawed	Air seasoned	384				3.93	1905	A. T. & S. F.	Garnet, Kan.	
	Hewed	Air seasoned	500				5.0	1910	A. T. & S. F.	Hutchinson cut-off	
	Sawed	Air seasoned	500				5.0	1910	A. T. & S. F.	Hutchinson cut-off	
	Hewed	Air seasoned	24238				Less than 5	1906	A. T. & S. F.	Ottawa cut-off	
	Hewed	Seasoned	149				5.0	1913	A. T. & S. F.	Newton, Kan.	
	Sawed	Seasoned	151				5.0	1913	A. T. & S. F.	Newton, Kan.	
PINE — SOUTHERN YELLOW UNTREATED											
7x8x8½	Sawed	Seasoned	32256	In South	21"			1909	P. S. & N.	New York	43% C. 57% T.

CONDITIONS							RESULTS						
% of Grade	Tie Plates		Kind of Spikes	Wt. of Rail, Lbs.	Ballast	Traffic Tons per Year	Date Inspected	Time of Service, Years	% Removed	Cause of Removal		Present Condition	Av'ge Life, Yrs.
	Kind	Size								Decay %	Wear %		
0.44	Goldie.		Cut	80	Slag		1917	10	0.2	Broken		Fair	
	Clark Tension		Screw	80	Gravel		1917	7.8	0			Good.	
			Cut				1917	11	22.9				
	I and W		Screw	90	Gravel		1917	11	68.7				
	Clark		Screw	90	Gravel		1917	6	.5				
	Clark		Screw	90	Gravel		1917	6	0				
	Clark		Screw	90	Gravel		1917	6	.5				
	Clark		Screw	90	Gravel		1917	6	0				
		6"x8"	Cut	85	Gravel		1917	12	43.8	2.6	10.9	Fair	
		7½"x9"	Cut	90	Rock		1917	12	42.3	4.2	33.5	Good	
		6"x8" 7½"x9"	Cut	85	Slag		1917	12	11.4	Wear			
		7½"x9"	Cut	90	Rock		1917	13	4.7	1.5	3.2		
		7½"x9"	Cut	90	Rock		1917	13	4.7	Wear			
		7½"x9	Cut	90	Rock		1917	13	0				
		7½"x9"	Cut	90	Rock		1917	13	0				
		7½"x9"	Cut	90	Rock		1917	12	18.7	13.1	5.6		
		7½"x9"	Cut	90	Rock		1917	7	0.2	.13	Burned		
		7½"x9"	Cut	90	Rock		1917	7	0.1	0.1	Wear		
		6"x8"	Cut	85	Rock		1917	11	0.1	Wear			
		7½"x9"	Cut	85	Rock		1917	4	0				
		7½"x9"	Cut	85	Rock		1917	4	0				
0 15	Walhaupter		Cut	85	Gravel and Slag	4,000,000	1917	8	30	Decay			

DESCRIPTION OF MATERIAL								SERVICE			
Dimensions	Form	Preparation	No. of Ties in Test	Where Grown	Spacing in Track	Average Absorption Lbs. per Tie	Average Absorption Lbs. per Cu.ft.	Date placed	Name of R. R.	Location	Curve or Tangent
PINE — SOUTHERN YELLOW ZINC CHLORIDE — BURNETT											
....	Hewed	Seasoned..	6357	....	....	.....	0.58	1904	A. T. & S. F..	Newton, Kan..	....
....	Hewed	Seasoned..	9251	....	....	.....	0.58	1905	A. T. & S. F..	Newton, Kan..	....
....	Sawed.	Seasoned..	2517	....	....	...	0.52	1904	A. T. & S. F..	Newton, Kan..	....
....	Sawed.	Seasoned..	40	....	....	.....	0.52	1905	A. T. & S. F..	Newton, Kan..	....
6x8x8...	Sawed.	Air Seasoned not bored for Spikes...	496	Texas. ...	19 to rail......	1½	0.50	1906	C. M. & St. P.	Okaton, S. D..	53.8% C.
6x8x8...	....	Seasoned..	500	....	....	.....	0.50	1906	C. M. & St. P.	½ mi. West Morrison, S. D........	....
PINE — SOUTHERN YELLOW ZINC — CREOSOTE											
7x9x9...	Hewed	....	433	....	....	1.01# zn. cl. 17.7# creo.	4.49 Creo.	1907	G. H. & S. A.	Witherow and Salix, La....	....
7x9x9...	Hewed	....	476	....	....	1.01# zn. cl. 17.7# creo.	4.49 Creo.	1906	G. H. & S. A..	Lafayette and Scott.......	....
PINE — SOUTHERN YELLOW ZINC TANNIN — WELLHOUSE											
....	Hewed	Seasoned 6 mos....	25	....	....	.....	......	1897	N. & S........	Norfolk Div...	2° C.
....	Hewed	Seasoned 6 mos....	100	....	....	.....	......	1897	N. & S........	Norfolk Div...	Tangent.
....	Sawed.	Seasoned.. 6 mos....	100	....	....	.....	......	1897	N. & S........	Norfolk Div...	Tangent.
PINE — WESTERN YELLOW ZINC CHLORIDE — BURNETT											
....	....	....	6354	....	....	.....	0.33 to 0.40	1900 to 1901	C. B. & Q.....	Sidney, Neb...	....
....	....	....	3157	....	....	.....	0.33 to 0.40	1906	C. B. & Q.....	Casper, Wyo. Div........	....
....	Sawed Trian	gular.......	56	....	....	......	0.50	1911	G. N..........	Butte Div.....	T. 70% C. 30%
....	Sawed Square	....	1327	....	....	......	0.50	1911	G. N..........	Butte Div.....	T. 70% C. 30%
....	Hewed	....	3324	....	....	......	0.50	1911	G. N..........	Butte Div.....	T. 70% C. 30%
....	Sawed Square	....	1367	....	....	......	0.75	1911	G. N..........	Butte Div.....	T. 70% C. 30%
....	Sawed Trian	gular.......	1899	....	....	......	0.75	1911	G. N..........	Butte Div.....	T. 70% C. 30%
....	....	....	2916	....	....	......	0.50	1903	G. N..........	Moravia, Idaho	T. 20% 4°-30′ 2°-30′
....	Triang	ular........	2562	....	....	......	0.75	1907	G. N..........	Hobson, Mont.	T. 40% C. 60%
....	Triang	lar.........	2601	West. Mont	....	......	0.50	1902	G. N..........	Conrad, Mont.	Tangent.

CONDITIONS							RESULTS						
% of Grade	Tie Plates		Kind of Spikes	Wt. of Rail, Lbs.	Ballast	Traffic Tons per Year	Date Inspected	Time of Service, Years	% Removed	Cause of Removal		Present Condition	Av'ge Life, Yrs.
	Kind	Size								Decay %	Wear %		
		7½"x9"	Cut	85	Rock	15,034,755	1917	13	47.5	Decay			
		7½"x9"	Cut	85	Rock	15,034,755	1917	12	43.8	37.3	6.5		
		7½"x9"	Cut	85	Rock	15,034,755	1917	13	59.2	Decay			
		7½"x9"	Cut	85	Rock	15,034,755	1917	12	55.0	Decay			
		None	Cut	60	Gravel	Medium	1916	10	0			94.8% Good	
			Cut	85	Sand	Heavy	1917	11	86	Rail cut and	decay	Fair	
	C. S. N	o. 37	Cut		Gravel		1917	10	83.2	Decay and Dera	ilment		
	I. and W		Cut		Gravel		1917	11	35.4				
	Servis						1917	20	94				
	Servis						1917	20	94				
	Servis						1917	20	89				
	On Cur	ves	Cut	75	Peety Gra	vel	1917	17	21	Decay		Good	
	None		Cut	65	Gravel		1917	11	1.6			Good	
	Goldie	6½x8½	Cut	90	Gravel		1917	6½	0			Good	
	Goldie	6½x8½	Cut	90	Gravel		1917	6½	0.1	Decay		Good	
	Goldie	6½x8½	Cut	90	Gravel		1917	6½	0.2	Decay		Good	
	Goldie	6½x8½	Cut	90	Gravel		1917	6½	0.2	Decay		Good	
	Goldie	6½x8½	Cut	90	Gravel		1917	6½	0			Good	
0 5	Goldie	6½x8½	Cut	90	Gravel	6,052,224	1917	14	100	Decay and Sp	lit		8.4
	Glendo Sargen	n t	Cut	85	Gravel	2,146,500	1917	10	1.5	Decay			
0.5 and 0 6	None		Cut	68	Gravel	2,150,434	1917	15	86.1	Decay and Sp	lit		

DESCRIPTION OF MATERIAL								SERVICE			
Dimensions	Form	Preparation	No. of Ties in Test	Where Grown	Spacing in Track	Average Absorption Lbs. per Tie	Average Absorption Lbs. per Cu.ft.	Date placed	Name of R. R.	Location	Curve or Tangent
SPRUCE MERCURIC CHLORIDE — KYAN											
6x8x8		Seasoned 6 mos.	25		18 to rail			1911	C. M. & St. P.	Hartford, Wis.	Tangent.
TAMARACK CREOSOTE — OPEN TANK											
		Various seasoning	19		19 to rail	15.5		1907	C. & N. W.	Janesville, Wis.	
TAMARACK UNTREATED											
6x8x8	Hewed	Peeled Seasoned 23 mos.	25		19 to rail			1907	C. & N. W.	Janesville, Wis.	
6x8x8	Hewed	Unpeeled Seasoned 23 mos.	25		19 to rail			1907	C. & N. W.	Janesville, Wis.	
6x8x8	Hewed	Peeled Seasoned 35 mos.	20		19 to rail			1907	C. & N. W.	Janesville, Wis.	
6x8x8	Hewed	Unpeeled Seasoned 11 mos.	60		19 to rail			1907	C. & N. W.	Janesville, Wis.	
7x9x8	Sawed and Hewed	Unseasoned	2894	West Mont.	18 to rail			1908	G. N.	Newport, Wash.	Tang.80% 1°-15′ Cur.
7x9x8	Sawed.	Seasoned	2916.		18 to rail			1908	G. N.	Rimrock, Mont.	Tang 9.1% 3°-30′ Cur.
7x9x8	Sawed.		2989					1908	G. N.	Judith Gap, Mont.	Tang.60%
TAMARACK ZINC CHLORIDE — BURNETT											
6x8x8	Hewed	Seasoned 3 mos. unpeeled; 7 mos. peeled	125		19 to rail		0.51	1907	C. & N. W.	Janesville, Wis.	
6x8x8	Hewed	Seasoned 3 mos. unpeeled; 7 mos. peeled	125		19 to rail		0.508	1907	C. & N. W.	Janesville, Wis.	
6x8x8	Hewed	Seasoned 3 mos. unpeeled; 7 mos. peeled	125		19 to rail		0.508	1907	C. & N. W.	Janesville, Wis.	
6x8x8	Hewed	Peeled Seasoned 10 mos.	13		19 to rail		0.308	1907	C. & N. W.	Janesville, Wis.	
6x8x8	Hewed	Peeled Seasoned 10 mos.	25		19 to rail		0.26	1907	C. & N. W.	Janesville, Wis.	
7x9x8	Sawed.	Seasoned	2848	West. Mont.	16 to 30′ rail.		0.50	1903	G. N.	Granville, N.D.	Tangent.
	Hewed		2580				0.50	1903	G. N.	Glenberg, N.D.	Tangent.

CONDITIONS							RESULTS						
% of Grade	Tie Plates		Kind of Spikes	Wt. of Rail, Lbs.	Ballast	Traffic Tons per Year	Date Inspected.	Time of Service, Years	% Removed.	Cause of Removal		Present Condition	Av'ge Life, Yrs.
	Kind	Size								Decay %	Wear %		
Level	50% 50%	None Econo.	50% Cut 50% Screw	90	Gravel	Heavy	1917	6	0			96% good	
	Wolhaupter		Cut	90	Gravel	Light	1917	9.5	0			95% good	
	None		Cut	90	Gravel	Light	1917	9½	72	Decay			
	None		Cut	90	Gravel	Light	1915	7½	100	Decay			
	None		Cut	90	Gravel	Light	1917	9½	95	Decay			6.6
	None		Cut	90	Gravel	Light	1916	8½	100	Decay			6.5
0.40	N.P. No. 21 G.N. No. 58		Cut	90	Gravel	6,052,224	1917	9	99.2	Decay and split			7
0.50	N.P. No. 21 G.N. No. 58		Cut	90	Gravel	2,146,500	1917	9	84.3	Decay			
	Goldie on curves		Cut	85	Gravel	2,146,500	1917	9	57.2	Decay			
	Sellers		Screw	90	Gravel	Light	1917	9.5	0			98% good	
	Sellers		Cut	90	Gravel	Light	1917	9.5	0			96% good	
	Wolhaupter		Cut	90	Gravel	Light	1917	9.5	0			92% good	
	Wolhaupter		Cut	90	Gravel	Light	1917	9.5	0			69% good	
	Wolhaupter		Cut	90	Gravel	Light	1917	9.5	16			72% good	
0.40	None		Cut	60	Cinders and gravel	315,650	1917	14	33.2	Decay			
	None		Cut	60	Cinders and gravel	315,650	1917	14	25.2	Decay			

DESCRIPTION OF MATERIAL								SERVICE			
Dimensions	Form	Preparation	No. of Ties in Test	Where Grown	Spacing in Track	Average Absorption Lbs. per Tie	Average Absorption Lbs. per Cu.ft.	Date placed	Name of R. R.	Location	Curve or Tangent
TAMARACK ZINC TANNIN —— WELLHOUSE											
6x8x8...	....	Seasoned	46800	....	22"............	......	zn. cl. .443 Gel. .07 Tan. .086	1905	C. & N. W.....	Maribel, Wis...	Tangent.
6x8x8...	....	....	76000	....	22"............	......	zn. cl. .443 Gel. .07 Tan. .086	1905	C. & N. W.....	Laona, Wis....	98%Tang. 2% curve.
6x8x8...	Hewed	Peeled Seasoned 11 mos..	125	....	....	......	0.428	1907	C. & N. W.....	Janesville, Wis.	....
6x8x8...	Hewed	Unpeeled Seasoned 11 mos..	41	....	....	......	0.44	1907	C. & N. W.....	Janesville, Wis.	....
6x8x8...	Hewed	Unpeeled Seasoned 11 mos..	9	....	....	......	0.44	1907	C. & N. W.....	Janesville, Wis.	....
6x8x8...	Hewed	Unpeeled Seasoned 11 mos...	50	....	....	......	0.44	1907	C. & N. W.....	Janesville, Wis.	....
6x8x8...	Hewed	Unpeeled Seasoned 11 mos..	31	....	....	......	0.41	1907	C. & N. W.....	Janesville, Wis.	....
6x8x8...	Hewed	Peeled Seasoned 11 mos..	7	....	....	......	0.41	1907	C. & N. W.....	Janesville, Wis.	....
6x8x8...	Hewed	Peeled Seasoned 11 mos..	125	....	....	......	0.428	1907	C. & N. W.....	Janesville, Wis.	....
6x8x8...	Hewed	Unpeeled Seasoned 11 mos...	50	....	....	......	0.436	1907	C. & N. W.....	Janesville, Wis.	....
6x8x8...	Hewed	Peeled Seasoned 11 mos..	128	....	....	......	0.408	1907	C. & N. W.....	Janesville, Wis.	....
6x8x8...	Hewed	Unpeeled Seasoned 11 mos..	50	....	....	......	0.436	1907	C. & N. W.....	Janesville, Wis.	....
6x8x8...	Hewed	Peeled and Unpeeled Seasoned 10 mos...	59	....	....	......	0.424	1907	C. & N. W.....	Janesville, Wis.	....
6x8x8...	Hewed	Peeled and Unpeeled Seasoned 10 mos...	55	....	....	......	0.404	1907	C. & N. W.....	Janesville, Wis.	....
6x8x8...	Hewed	Peeled and Unpeeled Seasoned 10 mos...	58	....	....	......	0.376	1907	C. & N. W.....	Janesville, Wis.	....

ONDITIONS							RESULTS						
% of Grade	Tie Plates		Kind of Spikes	Wt. of Rail, Lbs.	Ballast	Traffic Tons per Year	Date Inspected	Time of Service, Years	% Removed	Cause of Removal		Present Condition	Av'ge Life, Yrs.
	Kind	Size								Decay %	Wear %		
	None		Cut	72	Gravel		1916	11	16.1			Fair	
	Wolhau curves	pter on only	Cut	74	Gravel		1916	11	1.6			Fair	
	Sellers		Screw	90	Gravel	Light	1917	9½	0			94.4%	good
	Sellers		Screw	90	Gravel	Light	1917	9½	0			94.1%	good
	Creo.w	ood	Screw	90	Gravel	Light	1917	9½	11.1			77.8%	good
			Screw	90	Gravel	Light	1917	9½	2			92% go	od
	Creo.w	ood	Screw	90	Gravel	Light	1917	9½	0			87.1%	good
	Sellers		Cut	90	Gravel	Light	1917	9½	0			100% g	ood
	Sellers		Cut	90	Gravel	Light	1917	9½	0			95.2%	good
	Sellers		Cut	90	Gravel	Light	1917	9½	0			94% go	od
	Wolhau	pter	Cut	90	Gravel	Light	1917	9½	0.8			82.9%	good
	Wolhau	pter	Cut	90	Gravel	Light	1917	9½	0			98% go	od
	Wolhau	pter	Cut	90	Gravel	Light	1917	9½	0			61% go	od
	Wolhau	pter	Cut	90	Gravel	Light	1917	9½	1.8			85.5%	good
	Wolhau	pter	Cut	90	Gravel	Light	1917	9½	1.7			87.6%	good

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